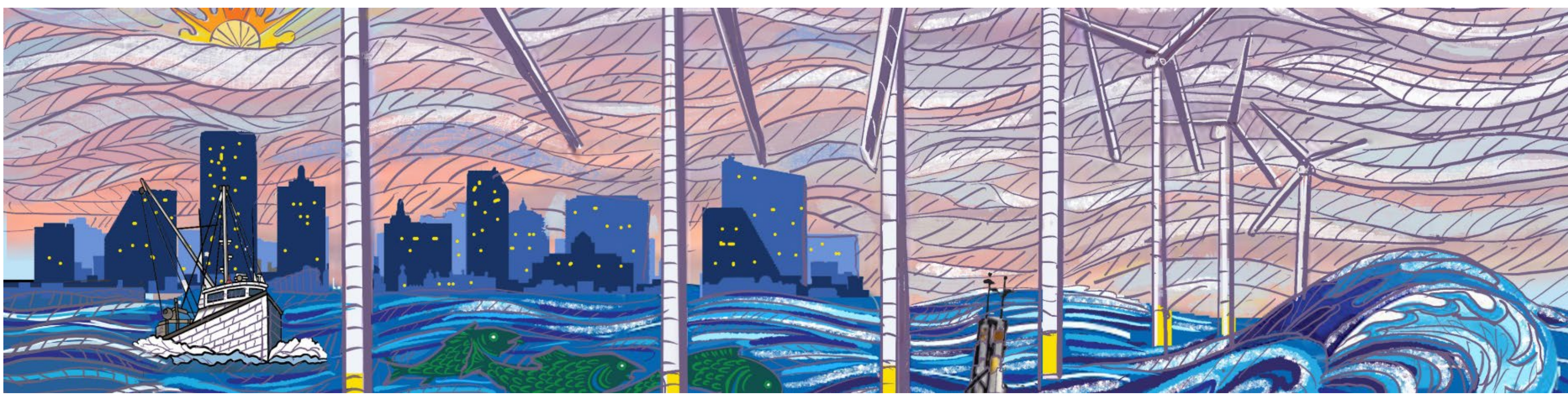

Appendix II-I

Electromagnetic Frequency (EMF) Report

Note:

On March 26, 2021, Atlantic Shores Offshore Wind, LLC (Atlantic Shores) submitted a Construction and Operations Plan (COP) to BOEM for the southern portion of Lease OCS-A 0499. On June 30, 2021, the New Jersey Board of Public Utilities (NJ BPU) awarded Atlantic Shores an Offshore Renewable Energy Credit (OREC) allowance to deliver 1,509.6 megawatts (MW) of offshore renewable wind energy into the State of New Jersey. In response to this award, Atlantic Shores updated Volume 1 of the COP to divide the southern portion of Lease OCS-A 0499 into two separate and electrically distinct Projects. Project 1 will deliver renewable energy under this OREC allowance and Project 2 will be developed to support future New Jersey solicitations and power purchase agreements.

As a result of the June 30, 2021 NJ BPU OREC award, Atlantic Shores updated Volume I (Project Information) of the COP in August 2021 to reflect the two Projects. COP Volume II (Affected Environment) and applicable Appendices do not currently include this update and will be updated to reflect Projects 1 and 2 as part Atlantic Shores' December 2021 COP revision.

ATLANTIC SHORES OFFSHORE WIND EMF STUDY REPORT

3	Issued for Review – Incorporated Epsilon Comments	12/24/2020	AZ	JT	JT
2	Issued for Review – Incorporated Atlantic Shores comments	12/02/2020	AZ	JT	JT
1	Issued for Review – Incorporated EDR comments	10/29/2020	AZ	JT	JT
0	Issued for Review	10/07/2020	AZ	JT	JT
REV.	**DESCRIPTION**	**DATE**	**PRP'D**	**CHK'D**	**APPR'D**
			SNC-Lavalin		

EXECUTIVE SUMMARY

Atlantic Shores Offshore Wind, LLC (Atlantic Shores), a 50/50 joint venture between EDF Renewables North America and Shell New Energies US LLC, is proposing to develop an offshore wind energy generation project (the Project) within Lease Area OCS-A 0499 located on the Outer Continental Shelf (OCS) within the New Jersey Wind Energy Area.

The proposed wind energy generation facility will be located in the southern approximately 102,000 acres (413 km^2) of the Lease Area, which is referred to as the Wind Turbine Area (WTA). Within the WTA, the Project will include up to 200 wind turbine generators (WTGs) and up to 10 offshore substations (OSSs). WTGs and OSSs will be connected by a system of 66 kilovolt (kV) – 150 kV inter-array cables. OSSs within the WTA will be interconnected by 66 kV – 275 kV inter-link cables.

WTGs will be aligned in a uniform grid with rows spaced 1.0 nautical mile (NM) (1.9 km) apart in an east-northeast direction and 0.6 NM (1.1 km) apart in a north-northwest direction. The OSS positions will also be located along the same east-northeast rows as the proposed WTGs, preserving 1.0 NM-wide (1.9 km-wide) corridors between structures.

At this stage of project development, the design of the facility is in early conceptualization phase. Various design options including the inter-array collection voltage, export voltage and technology, configuration of the OSSs, point of interconnection, etc. are being considered by the owner. Since a single design option has not been finalized at this stage of the project, this report provides calculated EMF from various system components considering the possible likely design combinations that may come to fruition during subsequent stages of project development.

Energy from the WTA is planned to be delivered to shore via either 230 kV to 275 kV high voltage alternating current (HVAC) or 320 kV to 525 kV high voltage direct current (HVDC) export cables. Up to four export cables will be installed within each of two possible Export Cable Corridors (ECCs), for a total of up to eight export cables. The export cables will traverse federal and state waters to deliver energy from the OSSs, and come onshore underground to landfall sites located in either Monmouth County (the "Monmouth Landfall Site") or Atlantic County (the "Atlantic Landfall Site") in New Jersey.

From the Monmouth and Atlantic Landfall Sites, new 230–525 kV HVAC or HVDC onshore interconnection transmission cables will travel underground along existing roadway, utility rights-of-way (ROWs), and/or along bike paths to up to two new substation sites (one for each onshore point of interconnection [POI]), where transmission will be stepped up or stepped down in preparation for interconnection with the electrical grid. Onshore interconnection transmission cables will continue from each of the new substations to proposed POIs to the electrical grid at the existing Larrabee Substation in Howell, New Jersey (for the Monmouth Landfall Site) or the existing Cardiff Substation in Egg Harbor Township, New Jersey (for the Atlantic Landfall Site).

This report presents the results of Electric and Magnetic Field (EMF) calculations for the offshore export cables and onshore interconnection routes that are proposed to convey the generated electricity by the

Project to one of three Candidate Substations (i.e., Cardiff 230 kV Substation, Larrabee 275 kV Substation, and an alternative location based in New York or New Jersey). A total of 52 study Cases were developed for right of ways containing either individually or combination of the inter-array, export and interconnection route cables. Additionally, four Cases were developed that comprised of offshore substations (OSS) and Onshore substation.

The electric field from the shielded power cables is blocked by the grounded cable armoring as well as the earth and therefore, the shielded cables will not be a direct source of any electric field outside the cables[1]. Accordingly, the modeling analysis presented in this report is limited to magnetic fields. More specifically, the modeling include an assessment of the magnetic fields from: 1) the inter-array cables running between individual WTGs and finally to the proposed OSS, 2) the offshore export cables running between the proposed OSS and landfall where the three core submarine cable splits into three separate single core cables in duct 3) the underground onshore export cables from the landfall to the proposed onshore substation, and 4) and overhead transmission lines (if required) connecting the project to one of the existing Candidate Substations.

For onshore substation cases where the substation is air insulated and has bare overhead bus conductors and the Case 47 for the overhead HV conductors between onshore substation and POI, both electric and magnetic field analyses are carried out.

At this stage of the project development, the inter-array cable and offshore export cable voltage levels and technology of electricity transmission are not finalized. A parametric analysis is therefore carried out to consider following variables:

1. IAC voltage level: 66 kV, 132 kV and 150 kV.
2. Offshore export cable voltage level: 230 kV AC, 275 kV AC, 320 kV DC and 525 kV DC

The modeling is conducted using the conservative assumption of full load operation 100% of the time. In reality the Project will operate at approximately a 50% annual capacity factor with correspondingly reduced current (amperage). All other things being equal, magnetic fields are proportional to current. Locations with unique EMF characteristics were examined, and the results obtained were compared with the corresponding maximum ICNIRP[2] limits.[3]

There are no federal standards limiting occupational or residential exposure to 60 Hertz (Hz) EMF in the United States. However, several states (including New Jersey) have set standards for transmission line electric and magnetic fields. These state guidelines are typically for “edge of right of way” and, in many instances, were established decades ago. New Jersey has an electric field guideline (3 kV/m, edge of right of way). NJDEP established this value as an interim standard in 1981. As stated above, the Project’s buried submarine and onshore cables will not be a source of electric fields. New Jersey does not have a magnetic field guideline or standard.

[1] The same is true for the Gas-insulated Switchgear bus bars where the grounded enclosure forces the electric field to be zero at the enclosure. Electric field analysis is therefore not conducted for Gas-insulated Switchgear.
[2] ICNIRP refers to International Commission on Non-Ionizing Radiation Protection
[3] Analysis of EMF and its impact on marine life is beyond scope of this EMF study.

The results indicate that the maximum EMF strengths obtained are within the allowable limits set by ICNIRP outside ROW. A value of 65 A/m (816.81 mG) was the maximum result of Magnetic Field at edge of ROW which relates to Case 50 (allowable limit is 400 A/m (5026.55 mG)). A value of 13.49 kV/m was the maximum result of Electric field inside the onshore 275/230 kV Substation which relates to Case 4 of substation cases (allowable limit is 8.33 kV/m). Since electric field is inversely proportional to the distance of measurement location from the energized object, increasing the bus heights of the OnSS can be used to mitigate higher electric fields.

Hence, the Project has no appreciable contribution to the surrounding environment outside ROW in terms of electric and magnetic field strengths.

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Acronyms and Abbreviations

A	Amperes
AC	Alternating Current
AIS	Air Insulated Substation
Al	Aluminum
ASOW	Atlantic Shores Offshore Wind
A/m	Ampere per meter
A/ph	Ampere per phase

CDEGS	Current Distribution, Electromagnetic Interference, Grounding and Soil Structure Analysis
Cu	Copper
DC	Direct Current
ECC	Export Cable Corridor
EMF	Electric and Magnetic Field
G	Gauss
HDD	Horizontal Directional Drilling
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
Hz	Hertz
ICNIRP	International Commission on Non-Ionizing Radiation
IEEE	Institute of Electrical and Electronics Engineers
kV	Kilovolt
kV/m	Kilovolt per meter
km	Kilometer
m	Meter
mG	Milligauss
mm	Millimeter
mT	Millitesla
MW	Megawatt
NJ	New Jersey
NM	Nautical Mile
NY	New York
OCS	Outer Continental Shelf
OnSS	Onshore Substation
OSS	Offshore Substation
POI	Point of Interconnection
ROW	Right of Way
SNC	SNC-Lavalin Inc.
T	Tesla
WTA	Wind Turbine Area
WTG	Wind Turbine Generator

1 Introduction

Atlantic Shores Offshore Wind, LLC is proposing to develop an offshore wind energy generation project within Lease Area OCS-A 0499 located in the New Jersey Wind Energy Area. The proposed facility will be located in the southern approximately 102,000 acres (413 km^2) of the Lease Area, which is referred to as the Wind Turbine Area (WTA). Within the WTA, the Project will include up to 200 wind turbine generators (WTGs) and up to 10 offshore substations (OSSs). WTGs and OSSs will be connected by a system of 66 kilovolt (kV) – 150 kV inter-array cables. OSSs within the WTA will be interconnected by 66 kV – 275 kV inter-link cables.

This report presents the Electric and Magnetic Field (EMF) calculations conducted using Current Distribution, Electromagnetic Interference, Grounding and Soil Structure Analysis (CDEGS) ver.16.2. The purpose of this study was to model the electrical facilities associated with the Project and calculate the resulting EMF produced by such facilities under maximum power generation scenario. Locations with unique EMF characteristics were examined, and the results obtained were compared with the corresponding maximum allowable limits. In the United States, there are no federal standards limiting occupational or residential exposure to 60 Hz EMF. However, several states have set standards for transmission line electric and magnetic fields. For the state of New Jersey, these values are listed in Table 1-1 with respect to rights-of-way (ROWs).

Table 1-1 New Jersey State Transmission Line Standards and Guidelines [1]

Electric Field (kV/m)		Magnetic Field (A/m)	
On ROW	Edge of ROW	On ROW	Edge of ROW
-	3	-	-

The International Commission on Non-Ionizing Radiation (ICNIRP), an independent organization that provides scientific advice and guidance on the human health and environmental effects of non-ionizing radiation, determined reference level limits for exposure to 60-Hz and static magnetic and electric fields, these values are listed in Table 1-2 and Table 1-3.

Table 1-2 ICNIRP Guidelines for EMF Exposure to Time-varying Electric and Magnetic Fields [2]

Exposure (60 Hz)	Electric Field Strength (kV/m)	Magnetic Field Strength (A/m)	Magnetic Field Density [Tesla (T)]
Occupational	8.333	800	1×10^{-3}
General Public	4.167	160	2×10^{-4}

Table 1-3 ICNIRP Guidelines for EMF Exposure to Static Magnetic Field [3]

Exposure (DC)		Magnetic Field Strength (A/m)	Magnetic Field Density (T)
Occupational	Exposure of head and of trunk	1.6×10^{6}	2
	Exposure of limbs	6.4×10^{6}	8
General Public	Exposure of any part of the body	3.2×10^{5}	0.4
	Exposure of persons with implanted electronic medical devices and implants containing ferromagnetic material, and dangers from flying objects	400	5×10^{-4}

2 Project Facility Description

Atlantic Shores proposes to develop the offshore wind energy generation facility that will produce electricity generated by up to 200 offshore WTGs that will be carried over inter-array cables to an OSS where the voltage will be boosted to transmission levels. The electricity will be carried to land via offshore export cables at transmission voltage levels, to an onshore substation. One of the three candidate substations (i.e., Cardiff 230 kV Substation, Larrabee 275 kV Substation, and an alternative location based in New York or New Jersey) will serve as a POI to the local transmission electrical grid. At this stage of the project development, various inter-array cables and offshore export cable voltage levels and technology of electricity transmission are being considered. A parametric analysis is therefore carried out to consider following variables in this study:

1. Inter-array cable voltage level: 66 kV, 132 kV and 150 kV.
2. Offshore export cable voltage level: 230 kV AC, 275 kV AC, 320 kV DC and 525 kV DC

In the analysis, SNC relied on the provided documents which are covering preliminary scenarios, electrical architecture, cables and/or transmission line design geometry, usage, specifications, and various other types of information provided. The following are the main project components which provide critical variables that largely affect EMF study results:

1. Inter-array cables
2. Offshore substation (OSS)
3. Offshore export cables and Onshore transmission cables
4. Onshore substation

3 Analysis Development

SNC calculated the fields from the project facilities at the maximum theoretical loadings, configuration of the ROW, cable construction, OSS and onshore substations provided by Atlantic Shores. Based on the provided data, the induced EMF were calculated and compared with relevant thresholds.

3.1 Input data collected

Table 3-1 summarizes the input data collected from Atlantic Shores (refer to the documents listed under References at the end of this report for the basis of this information).

Table 3-1 Summary of offshore and onshore modeling configurations

Configuration	Description	Numerical Value
Inter-Array Cables	Voltage	66 kV, 132 kV, 150 kV
	Current	950 Amperes (A)
	Cable Cross Section	1200 square millimeter (mm^2) AL
HVAC Offshore Export Cables	Voltage	230 kV, 275 kV
	Current	1200 A
	Cable Cross Section	2000 mm^2 CU
HVDC Offshore Export Cables	Voltage	320 kV, 525 kV
	Current	2000 A
	Cable Cross Section	2500 mm^2 CU
HVAC Onshore Interconnection Transmission Cables	Voltage	230 kV, 275 kV
	Current	1200 A
	Cable Cross Section	3000 mm^2 CU
HVAC OSS Platform	Voltage	66 kV, 132 kV, 150 kV Gas-insulated Switchgear Bays, 230 kV/275 kV Gas-insulated Switchgear Bays
	Current	950 A/ph of inter-array cables. 1200 A/ph for offshore export cable and OSS inter-link cables 502 A/ph for Shunt Reactors
	Decks	Cellar, Cable, Main, Utility, Roof Decks
HVDC OSS Platform	Voltage	66 kV, 132 kV, 150 kV Gas-insulated Switchgear Bays, 400 kV Gas-insulated Switchgear Bays
	Current	950 A/ph of inter-array cables. 1200 A/ph for offshore export cable
	Decks	6 Decks (Deck 1-Deck 6)
Onshore Substation	Voltage	230 kV
	Current	1200 A/ph of each offshore export cable. 1200 A/ph of overhead line connection to POI substation
	Route Options	Cardiff POI, NJ Larrabee POI, NJ

3.2 EMF Scenarios

Based on the data collected and possible variants in terms of inter-array cable voltage, offshore export and onshore transmission cable voltage and transmission technology, a number of EMF study cases were developed for the parametric analysis of highest possible EMF from the main project components (mentioned in Section 0). The developed study cases are shown in Tables 3-2 to 3-6. The results for the inter-array cable cases show that the magnetic fields are highest for assessment at the seabed than at 3.28 feet (1m) above seabed quite pertinently so as the fields are assessed at a distance closer to the cable at the seabed. The analysis of the remaining submarine cables is therefore considering assessment only at the seabed.

Table 3-2 Study Cases Developed for Inter-Array Cables

Case no.	COP Option (Route)	Circuit Name	Conductor Size	Laying arrangement
1	ALL	66 kV Medium Voltage Inter-Array Cable	1200 mm² Al	Inter-array cables alone in lease area (corridor with 8 cables). EMF assessment at seabed
2				Inter-array cables alone in lease area (corridor with 8 cables). EMF assessment at 3.28 feet (1 m) above seabed
3		132 kV Medium Voltage Inter-Array Cable	1200 mm² Al	Inter-array cables alone in lease area (corridor with 8 cables). EMF assessment at seabed
4				Inter-array cables alone in lease area (corridor with 8 cables). EMF assessment at 3.28 feet (1 m) above seabed
5		150 kV Medium Voltage Inter-Array Cable	1200 mm² Al	Inter-array cables alone in lease area (corridor with 8 cables). EMF assessment at seabed
6				Inter-array cables alone in lease area (corridor with 8 cables). EMF assessment at 3.28 feet (1 m) above seabed

Table 3-3 Study Cases Developed for Cables at Offshore Substations

Case no.	COP Option (Route)	Circuit Name	Conductor Size	Laying arrangement
7	ALL	At OSS where inter-array cable homeruns and offshore export cables are congregated	1200 mm² Al	OSS 1 (800 MW) - 10 inter-array cables (66 kV) & 4 offshore export cables (230 kV) including OSS interlink cables. EMF assessment at seabed
8				OSS 1 (800 MW) - 10 inter-array cables (66 kV) & 4 offshore export cables (275 kV) including OSS interlink cables. EMF assessment at seabed
9				OSS 1 (800 MW) - 6 inter-array cables (132 kV) & 4 offshore export cables (230 kV) including OSS interlink cables. EMF assessment at seabed

Case no.	COP Option (Route)	Circuit Name	Conductor Size	Laying arrangement
10				OSS 1 (800 MW) - 6 inter-array cables (132 kV) & 4 offshore export cables (275 kV) including OSS interlink cables. EMF assessment at seabed
11				OSS 1 (800 MW) - 6 inter-array cables (150 kV) & 4 offshore export cables (230 kV) including OSS interlink cables. EMF assessment at seabed
12				OSS 1 (800 MW) - 6 inter-array cables (150 kV) & 4 offshore export cables (275 kV) including OSS interlink cables. EMF assessment at seabed
13			1200 mm^2 Al	OSS 2 (12000 MW) - 16 inter-array cables (66 kV) & 5 offshore export cables (230 kV) including OSS interlink cables. EMF assessment at seabed
14				OSS 2 (12000 MW) - 16 inter-array cables (66 kV) & 5 offshore export cables (275 kV) including OSS interlink cables. EMF assessment at seabed
15				OSS 2 (1200 MW) - 8 inter-array cables (132 kV) & 5 offshore export cables (230 kV) including OSS interlink cables. EMF assessment at seabed
16				OSS 2 (1200 MW) - 8 inter-array cables (132 kV) & 5 offshore export cables (275 kV) including OSS interlink cables. EMF assessment at seabed
17				OSS 2 (1200 MW) - 8 inter-array cables (150 kV) & 5 offshore export cables (230 kV) including OSS interlink cables. EMF assessment at seabed
18				OSS 2 (1200 MW) - 8 inter-array cables (150 kV) & 5 offshore export cables (275 kV) including OSS interlink cables. EMF assessment at seabed
19	Alternative Substation in New York or New Jersey HVDC Option		1200 mm^2 Al	OSS 3 (1200 MW) - 16 inter-array cables (66 kV) & One positive and One negative HVDC offshore export cables (320 kV or 525 kV). EMF assessment at seabed
20				OSS 3 (1200 MW) - 16 inter-array cables (66 kV) & One positive and One negative HVDC offshore export cables (525 kV). EMF assessment at seabed
21				OSS 3 (1200 MW) - 8 inter-array cables (132 kV) & One positive and One negative HVDC

Case no.	COP Option (Route)	Circuit Name	Conductor Size	Laying arrangement
				offshore export cables (320 kV or 525 kV). EMF assessment at seabed
22				OSS 3 (1200 MW) - 8 inter-array cables (132 kV) & One positive and One negative HVDC offshore export cables (525 kV). EMF assessment at seabed
23				OSS 3 (1200 MW) - 8 inter-array cables (150 kV) & One positive and One negative HVDC offshore export cables (320 kV or 525 kV). EMF assessment at seabed
24				OSS 3 (1200 MW) - 8 inter-array cables (150 kV) & One positive and One negative HVDC offshore export cables (525 kV). EMF assessment at seabed

Table 3-4 Study Cases Developed for Offshore Export Cables

Case no.	COP Option (Route)	Circuit Name	Conductor Size	Laying arrangement
25	ALL	HVAC Offshore Export Cable	2000 mm^2 Cu	Landfall Horizontal Direction Drill (HDD) profile - 3 offshore export cables (230 kV) NY Route. EMF assessment at seabed
26				Buried in Seabed (6’ from seabed) - 3 offshore export cables (230 kV) NY Route. EMF assessment at seabed
27				Landfall HDD profile - 3 offshore export cables (275 kV) NY Route. EMF assessment at seabed
28				Buried in Seabed (6’ from seabed) - 3 offshore export cables (275 kV) NY Route. EMF assessment at seabed
29				Landfall HDD profile - 4 e offshore export cables (230 kV) NJ Route. EMF assessment at Seabed
30				Buried in Seabed (6’ from seabed) - 4 offshore export cables (230 kV) NJ Route. EMF assessment at seabed
31				Landfall HDD profile - 4 offshore export cables (275 kV) NJ Route. EMF assessment at seabed
32				Buried in Seabed (6’ from Seabed) - 4 offshore export cables (275 kV) NJ Route. EMF assessment at seabed

Case no.	COP Option (Route)	Circuit Name	Conductor Size	Laying arrangement
33				Cable Crossing arrangement (refer to 09_29 A131951-0309-SX-LX-0 Cab Crossing layout [47]). Buried in seabed {4 feet (1.2 m) from seabed} - 3 offshore export cables (230 kV) NY Route. EMF assessment at seabed
34				Cable Crossing arrangement (refer to 09_29 A131951-0309-SX-LX-0 Cab Crossing layout [47]). Buried in seabed {4 feet (1.2 m) from seabed} - 3 offshore export cables (275 kV) NY Route. EMF assessment at seabed
35				Cable Crossing arrangement (refer to 09_29 A131951-0309-SX-LX-0 Cab Crossing layout [47]). Buried in seabed {4 feet (1.2 m) from seabed} - 4 offshore export cables (230 kV) NJ Route. EMF assessment at seabed
36				Cable Crossing arrangement (refer to 09_29 A131951-0309-SX-LX-0 Cab Crossing layout [47]). Buried in seabed {4 feet (1.2 m) from seabed} - 4 offshore export cables (275 kV) NJ Route. EMF assessment at seabed
37	Alternative Substation in New York or New Jersey NJ Route – Larrabee POI	320 kV HVDC Offshore Export bundled cable	2500 mm^2 Cu	Landfall HDD profile. EMF assessment at seabed
38				Buried in seabed (6' from seabed). EMF assessment at seabed
39				Cable Crossing arrangement (refer to 09_29 A131951-0309-SX-LX-0 Cab Crossing layout [47]). Buried in seabed {4 feet (1.2 m) from seabed}. EMF assessment at seabed.
40	Alternative Substation in New York or New Jersey NJ Route – Larrabee POI	525 kV HVDC Offshore Export Cable. Cable laid separately 328.08 feet (100 m) separation distance		Landfall HDD profile. EMF assessment at seabed
41				Buried in seabed (6' from seabed). EMF assessment at seabed
42				Cable Crossing arrangement (refer to 09_29 A131951-0309-SX-LX-0 Cab Crossing layout [47]). Buried in seabed {4 feet (1.2 m) from seabed}. EMF assessment at seabed.

Table 3-5 Study Cases Developed for Onshore Interconnection Transmission Cables

Case no.	COP Option (Route)	Circuit Name	Conductor Size	Laying arrangement
43	ALL	HVAC Onshore Interconnection Transmission Cable	3000mm^2 Cu Single Core	Trench - Narrow Corridor - 4 circuits - 230 kV interconnection transmission cables. EMF assessment at surface
44				Trench - Narrow Corridor - 4 circuits - 275 kV interconnection transmission cables. EMF assessment at surface
45				HDD - 3.28 feet (1 m) depth and 10 feet (3 m) separation - 4 circuits - 230 kV interconnection transmission cables. EMF assessment at surface
46				HDD - 3.28 feet (1 m) depth and 10 feet (3 m) separation - 4 circuits - 275 kV interconnection transmission cables. EMF assessment at surface
47	NJ Route – Larrabee POI	230 kV Overhead transmission line from Onshore Substation to Larrabee POI	Twin 1272 MCM ACSR	Overhead lines. EMF assessment at 3.28 feet above ground surface
48	Alternative Substation in New York POI NJ Route – Larrabee POI	320 kV HVDC Onshore interconnection transmission cable	2500 mm^2 Cu	Trench. EMF assessment at surface
49				HDD. EMF assessment at surface
50	Alternative Substation in New York POI NJ Route – Larrabee POI	525 kV HVDC Onshore interconnection transmission cable	2500 mm^2 Cu	Trench - Bipole Operation. EMF assessment at surface
51				HDD. EMF assessment at surface
52				Trench - Monopole Operation. EMF assessment at surface

Table 3-6 Study Cases Developed for Substations

Case no	COP Option (Route)	Substation Name
1	ALL	OSS 1 – 800 MW
2		OSS 2 –1200 MW
3	Alternative Substation in New York NJ Route – Larrabee POI	OSS 3 – 1200 MW HVDC
4	NJ Route – Cardiff POI NJ Route – Larrabee POI	OSS 230/230 kV or 275/230 kV

3.3 Assumptions and Approaches

1. As informed by Atlantic Shores, it is understood that the currents listed in Table 3-1 are the largest possible current that can ever flow in the project facility components. The actual current flows during maximum generation scenario are expected to be lower than the currents considered in this study.
2. Cases 19-24 and Case 3 (OSS 3-1200 MW HVDC) have both AC and DC cables. As a conservative approach, the overall (total) EMF are considered additive in nature.
3. For inter-array cables which are presented in Cases 1-24, the distance of outermost cables in a ROW to the edge of ROW is assumed to be 656.168 feet (200 m).
4. For offshore export cables which are presented in Cases 25-42, the distance of outermost cables in a ROW to the edge of ROW is assumed to be 820.21 feet (250 m).
5. For onshore interconnection transmission cables which are presented in Cases 43-52, the distance of outermost cables in a ROW to the edge of ROW is assumed to be3.28 feet (1 m).
6. The cable sheaths are assumed grounded at both sending and receiving ends.
7. Soil resistivity, relative permittivity and relative permeability of sea water are assumed to be 0.2 ohm.meter (ohm. m) 72 and 1 respectively [4,5,6]. Soil resistivity, relative permittivity and relative permeability of seabed are assumed to be 0.91 ohm.m, 30 and 1 respectively [4,5,6]. For the onshore cases, soil resistivity, relative permittivity and relative permeability are assumed to be 150 ohm.m, 1 and 1, respectively.
8. For the OSS cases, EMF have been assessed at all decks as well as at sea level. The EMF at OSS decks are compared with the respective occupational limits. The EMF at sea level are compared with general public limits.
9. For the onshore substation cases, EMF have been assessed at 3.28 feet (1 m) above finished grade. The EMF inside the substation fence are compared with the respective occupational limits. The EMF outside the substation fence are compared with general public limits.
10. As noted previously, the EMF assessment for the cases comprising only of cables and/or Gas-insulated Switchgear buses, is limited to assessment of magnetic fields. For all other cases both Magnetic and Electric Fields are assessed.

4 EMF Results

The following subsections present the results obtained from CDEGS models of the study cases developed in Tables 3-2 to 3-6 for both magnetic and electric fields.

4.1 Magnetic Field Results for Cable Cases

4.1.1 Case 1

Case 1 is for 66 kV Medium Voltage Inter-Array Cables (1200 mm^2 Al). Inter-array cables alone in lease area (corridor with 8 cables). EMF assessment at seabed.

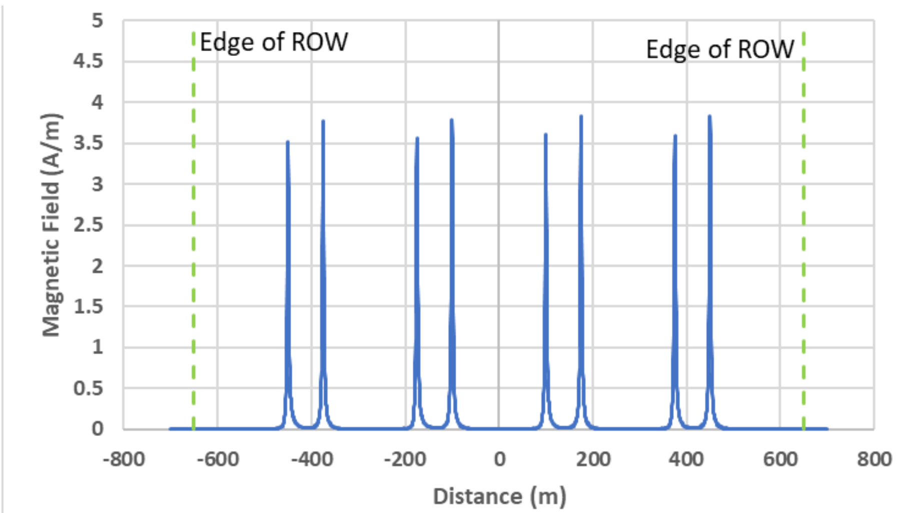

Figure 4-1 Magnetic Field Result of Case 1

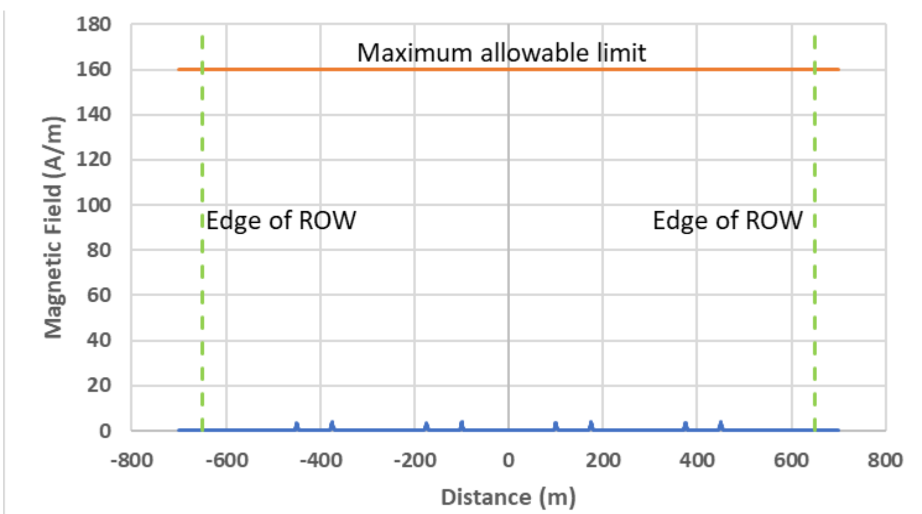

Figure 4-2 Magnetic Field Result of Case 1 with Maximum Allowable Limit

4.1.2 Case 2

Case 2 is for 66 kV Medium Voltage Inter-Array Cables (1200 mm^2 Al). Inter-array cables alone in lease area (corridor with 8 cables). EMF assessment at 3.28 feet (1 m) above seabed.

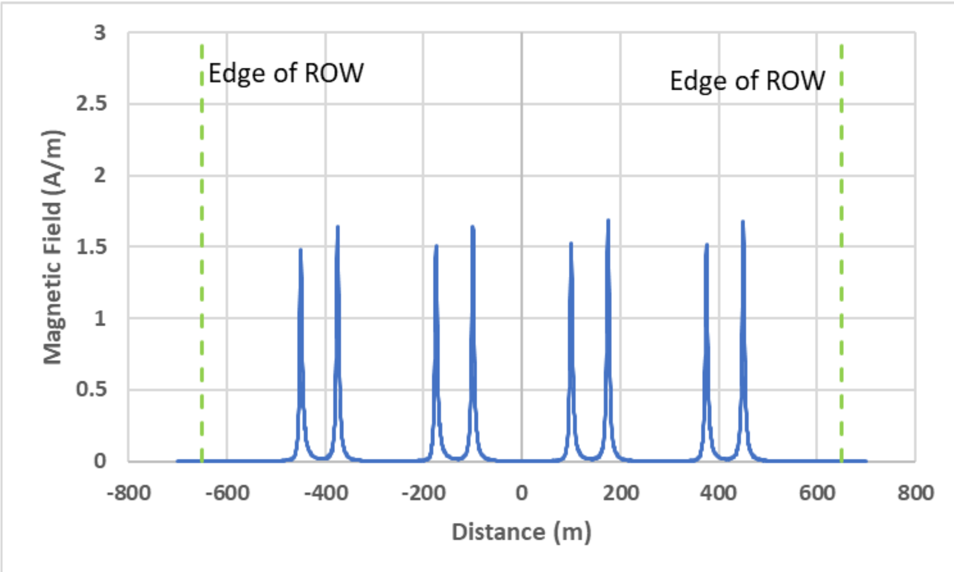

Figure 4-3 Magnetic Field Result of Case 2

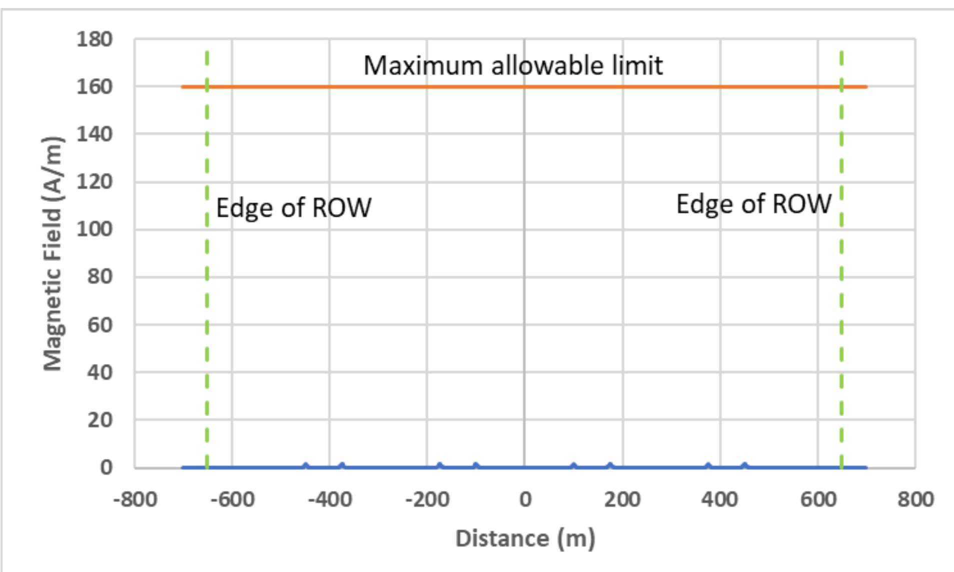

Figure 4-4 Magnetic Field Result of Case 2 with Maximum Allowable Limit

4.1.3 Case 3

Case 3 is for 132 kV Medium Voltage Inter-Array Cable (1200 mm^2 Al). Inter-array cables alone in lease area (corridor with 8 cables). EMF assessment at seabed.

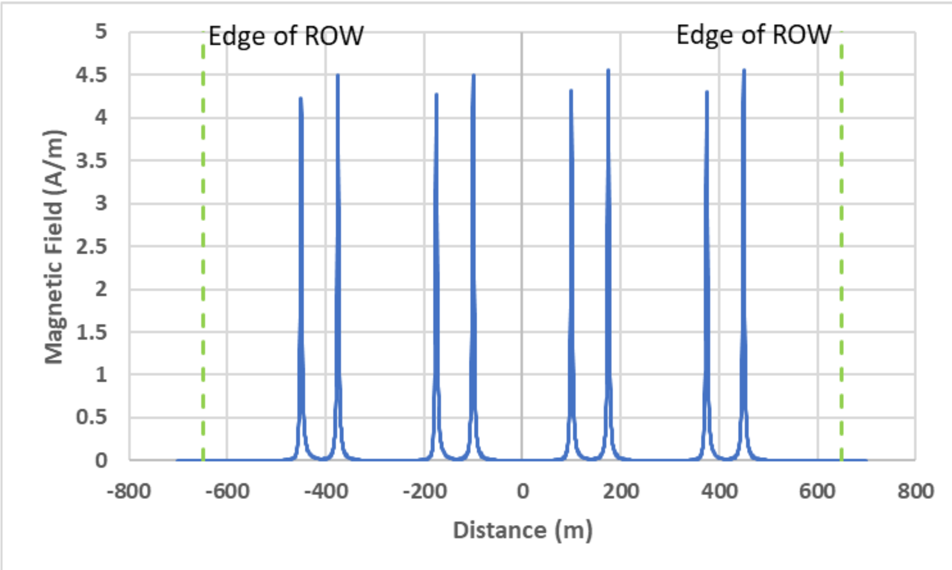

Figure 4-5 Magnetic Field Result of Case 3

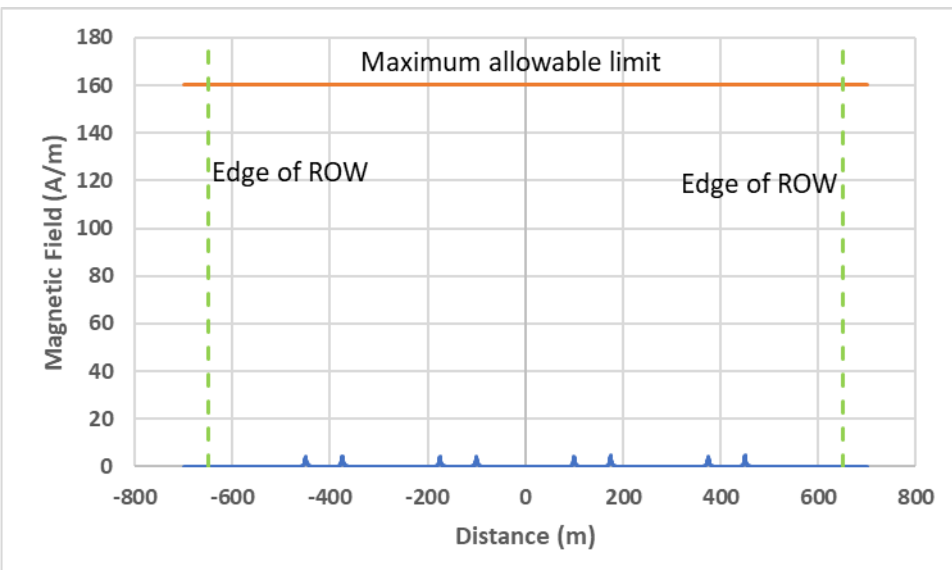

Figure 4-6 Magnetic Field Result of Case 3 with Maximum Allowable Limit

4.1.4 Case 4

Case 4 is for 132 kV Medium Voltage Inter-Array Cable (1200 mm^2 Al). Inter-array cables alone in lease area (corridor with 8 cables). EMF assessment at 3.28 feet (1 m) above seabed.

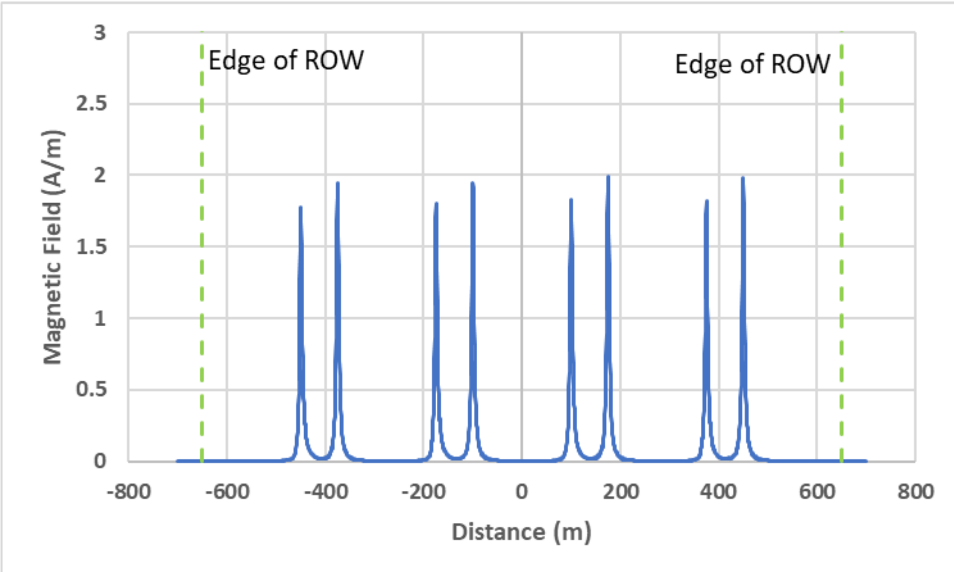

Figure 4-7 Magnetic Field Result of Case 4

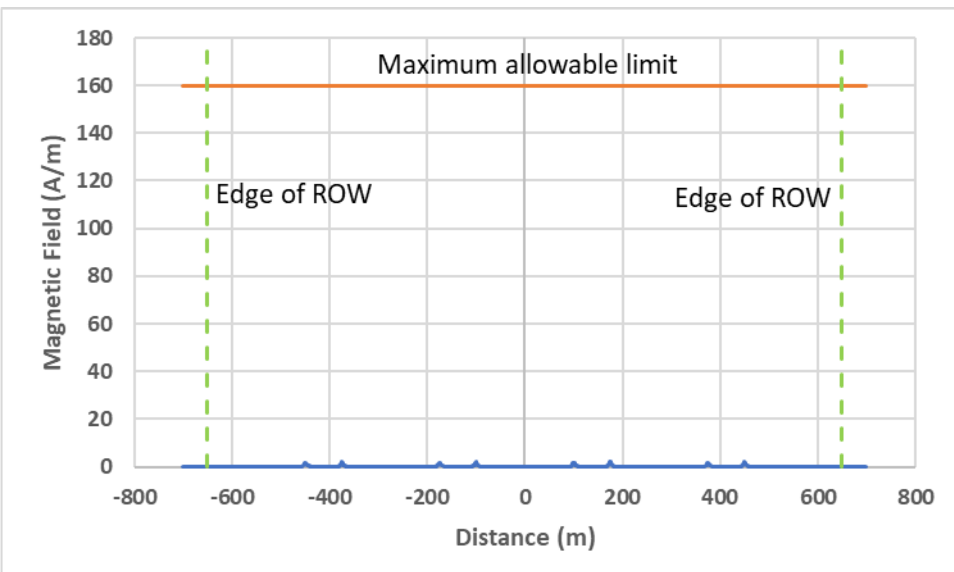

Figure 4-8 Magnetic Field Result of Case 4 with Maximum Allowable Limit

4.1.5 Case 5

Case 5 is for 150 kV Medium Voltage Inter-Array Cable (1200 mm^2 Al). Inter-array cables alone in lease area (corridor with 8 cables). EMF assessment at seabed.

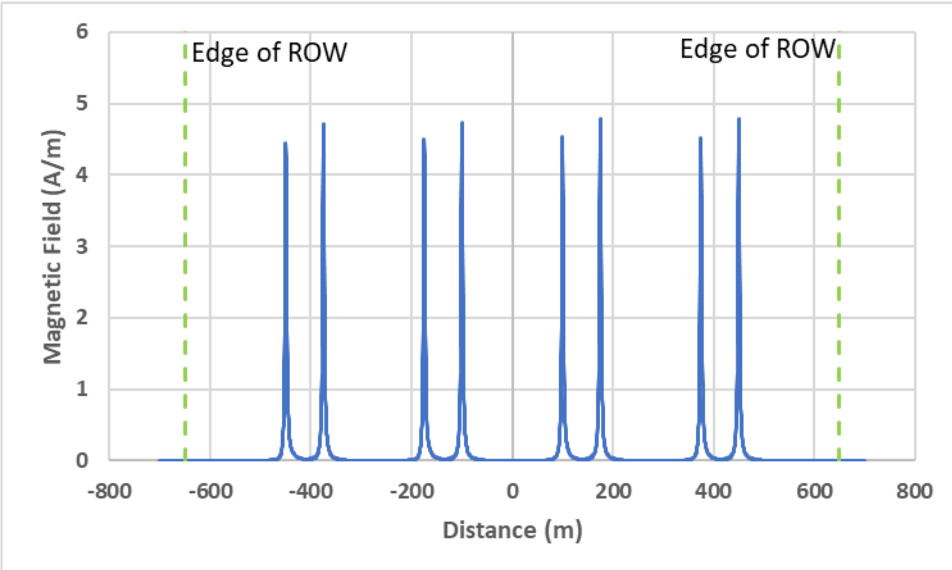

Figure 4-9 Magnetic Field Result of Case 5

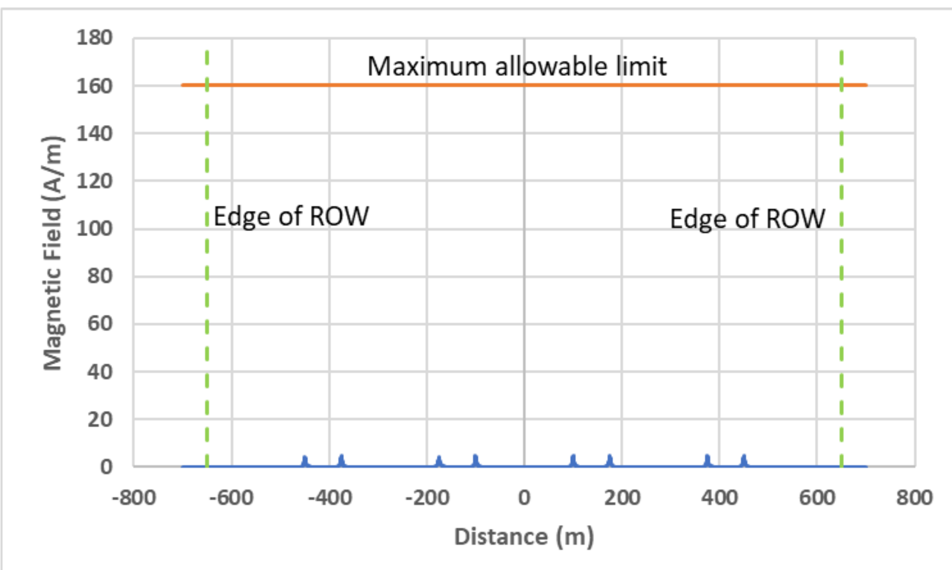

Figure 4-10 Magnetic Field Result of Case 5 with Maximum Allowable Limit

4.1.6 Case 6

Case 6 is for 150 kV Medium Voltage Inter-Array Cable (1200 mm^2 Al). Inter-array cables alone in lease area (corridor with 8 cables). EMF assessment at 3.28 feet (1m) above seabed.

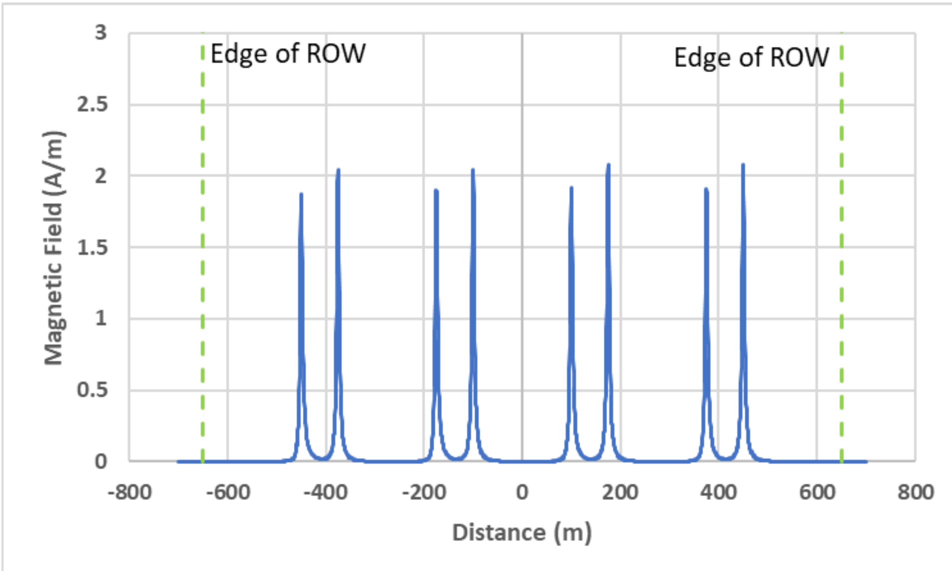

Figure 4-11 Magnetic Field Result of Case 6

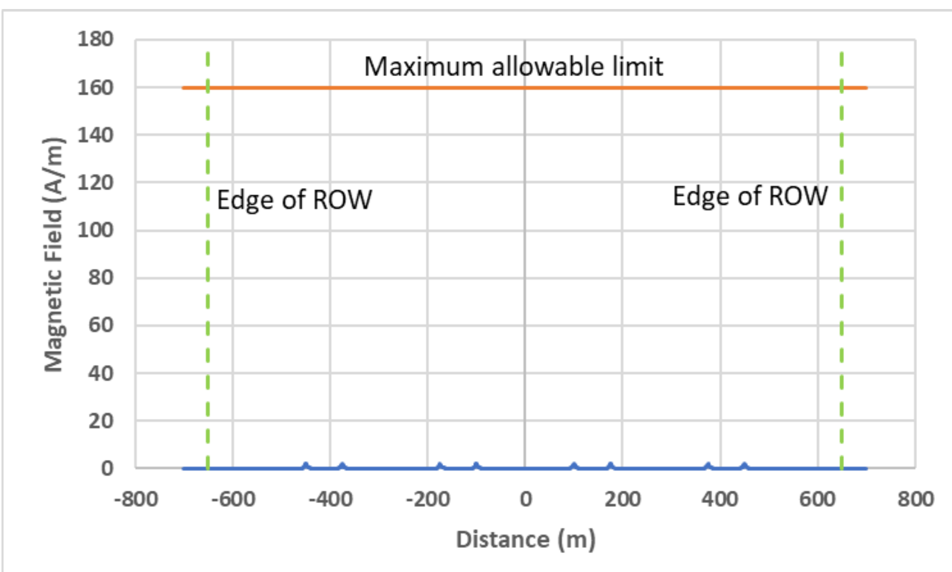

Figure 4-12 Magnetic Field Result of Case 6 with Maximum Allowable Limit

4.1.7 Case 7

Case 7 is for OSS where inter-array cable homeruns and offshore export cables are congregated (1200 mm^2 Al). OSS 1 (800 MW) - 10 inter-array cables (66 kV) & 4 offshore export cables (230 kV) including OSS interlink cables. EMF assessment at seabed.

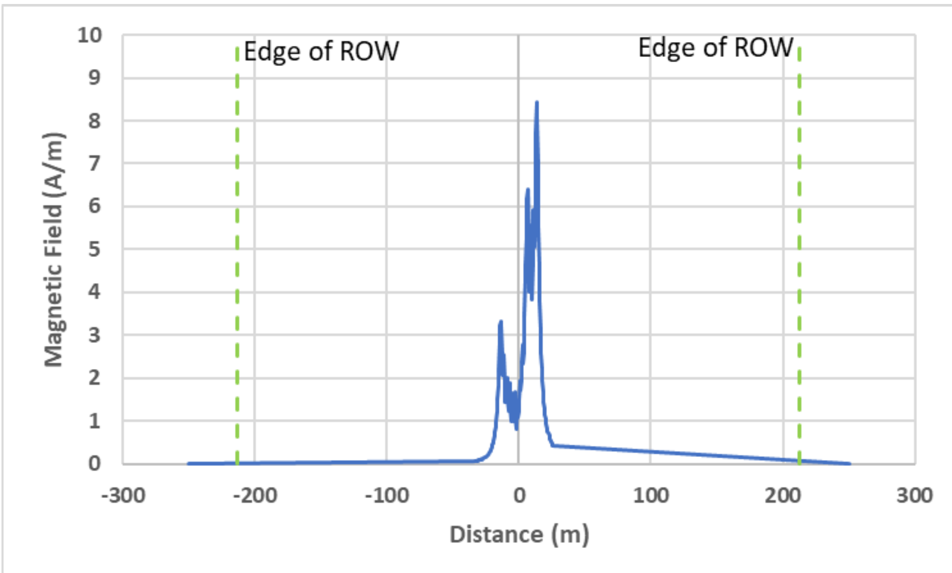

Figure 4-13 Magnetic Field Result of Case 7

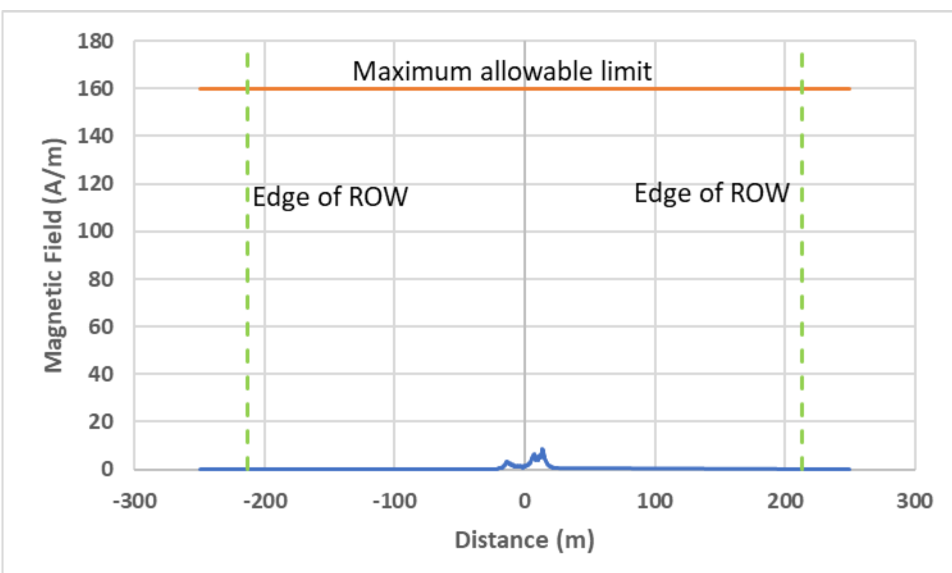

Figure 4-14 Magnetic Field Result of Case 7 with Maximum Allowable Limit

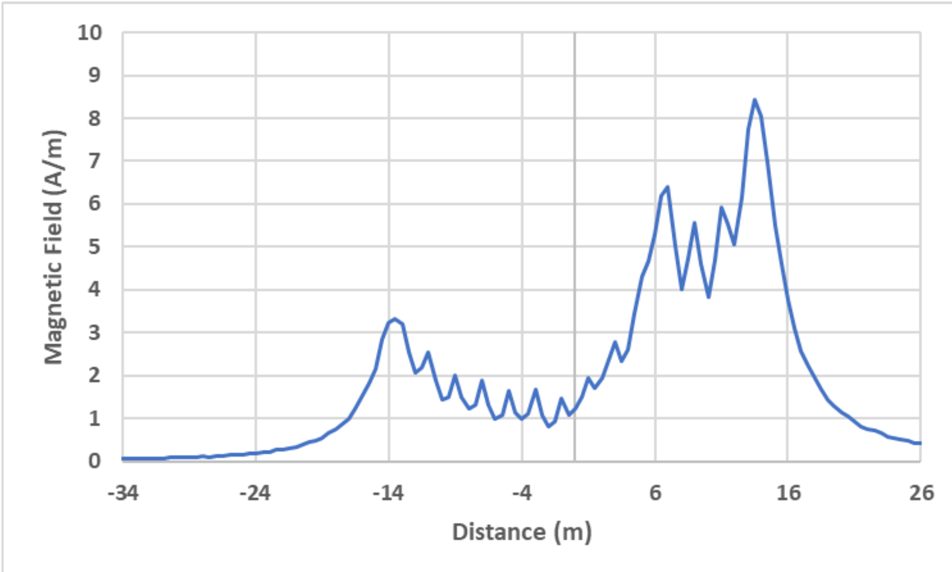

Figure 4-15 Zoomed Magnetic Field Result of Case 7

4.1.8 Case 8

Case 8 is for OSS where inter-array cable homeruns and offshore export cables are congregated (1200 mm^2 Al). OSS 1 (800 MW) - 10 inter-array cables (66 kV) & 4 offshore export cables (275 kV) including OSS interlink cables. EMF assessment at seabed.

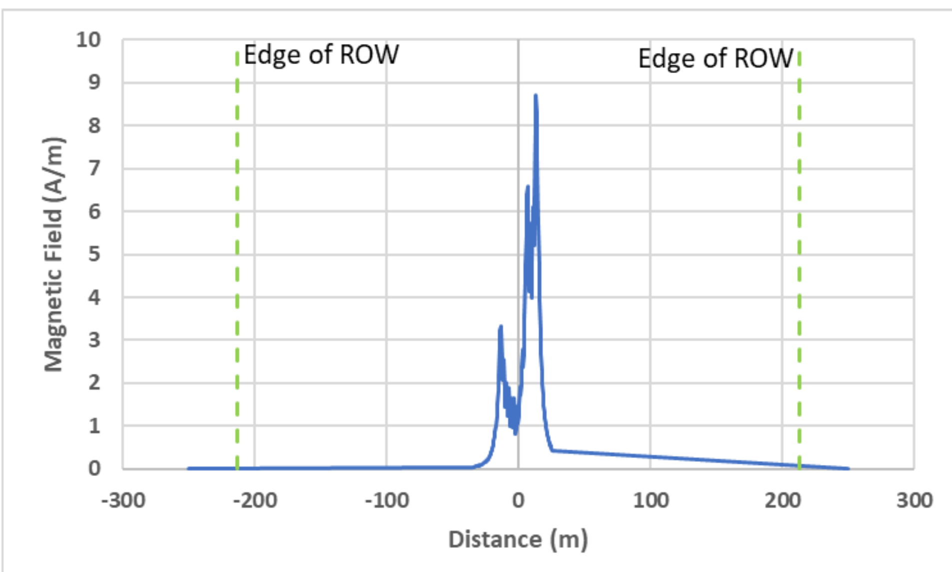

Figure 4-16 Magnetic Field Result of Case 8

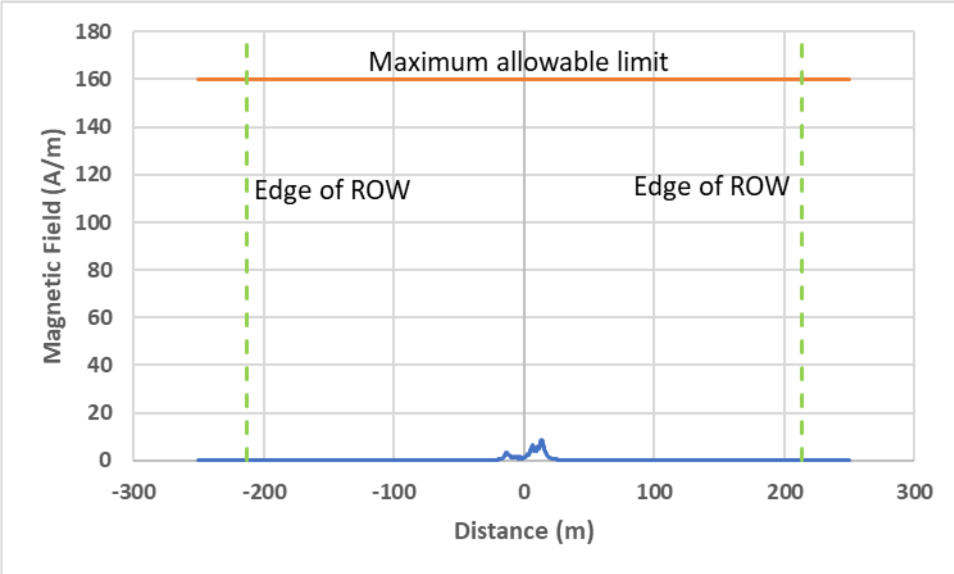

Figure 4-17 Magnetic Field Result of Case 8 with Maximum Allowable Limit

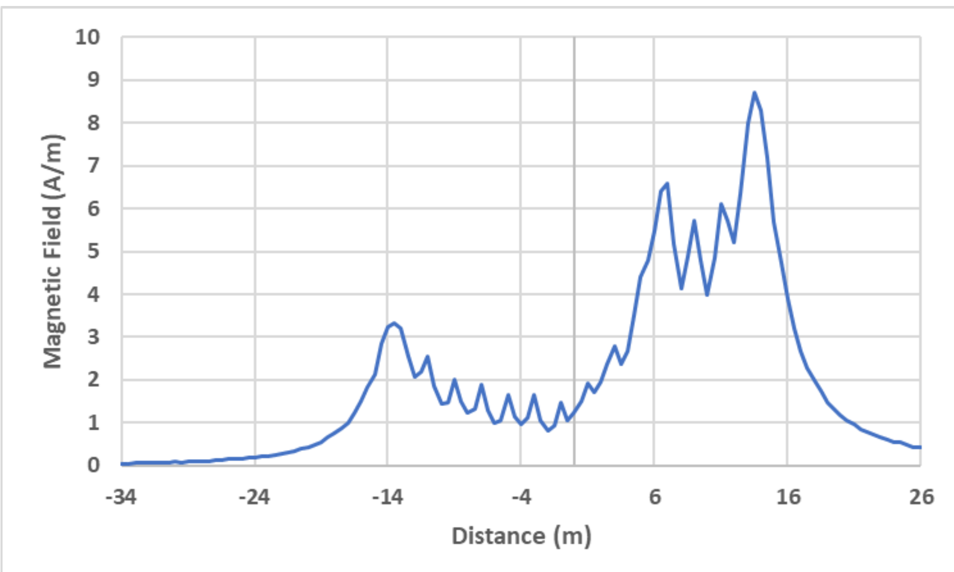

Figure 4-18 Zoomed Magnetic Field Result of Case 8

4.1.9 Case 9

Case 9 is for OSS where inter-array cable homeruns and offshore export cables are congregated (1200 mm^2 Al). OSS 1 (800 MW) - 6 inter-array cables (132 kV) & 4 offshore export cables (230 kV) including OSS interlink cables. EMF assessment at seabed.

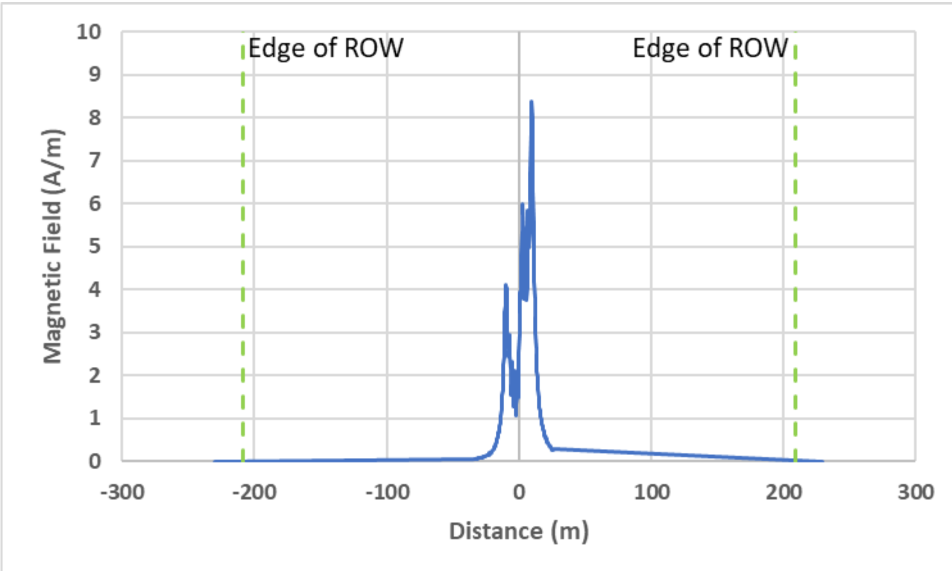

Figure 4-19 Magnetic Field Result of Case 9

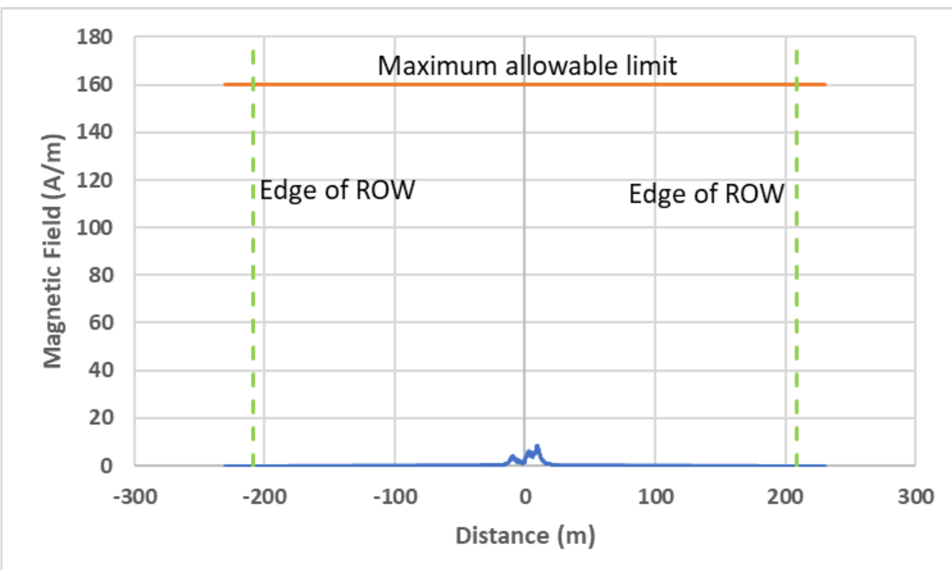

Figure 4-20 Magnetic Field Result of Case 9 with Maximum Allowable Limit

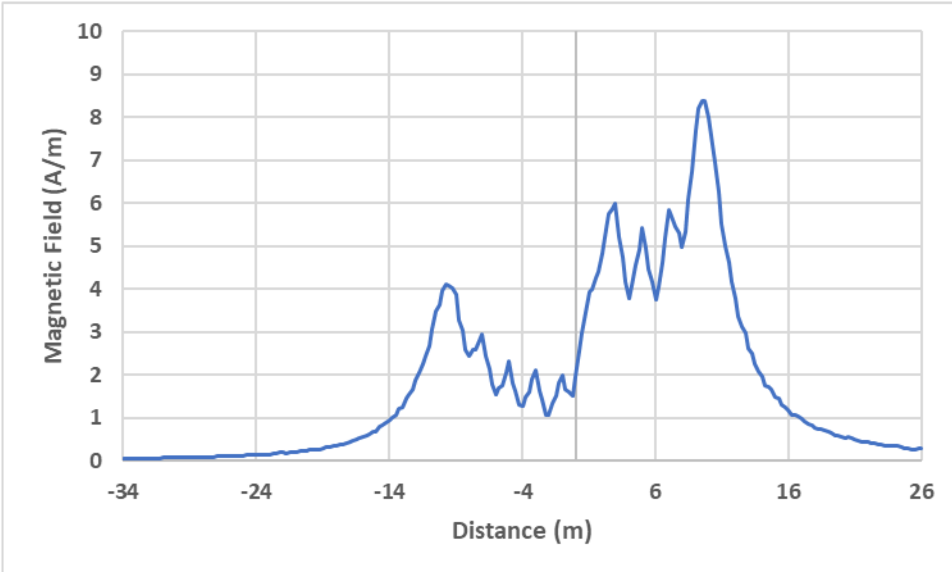

Figure 4-21 Zoomed Magnetic Field Result of Case 9

4.1.10 Case 10

Case 10 is for OSS where inter-array cable homeruns and offshore export cables are congregated (1200 mm^2 Al). OSS 1 (800 MW) - 6 inter-array cables (132 kV) & 4 offshore export cables (275 kV) including OSS interlink cables. EMF assessment at seabed.

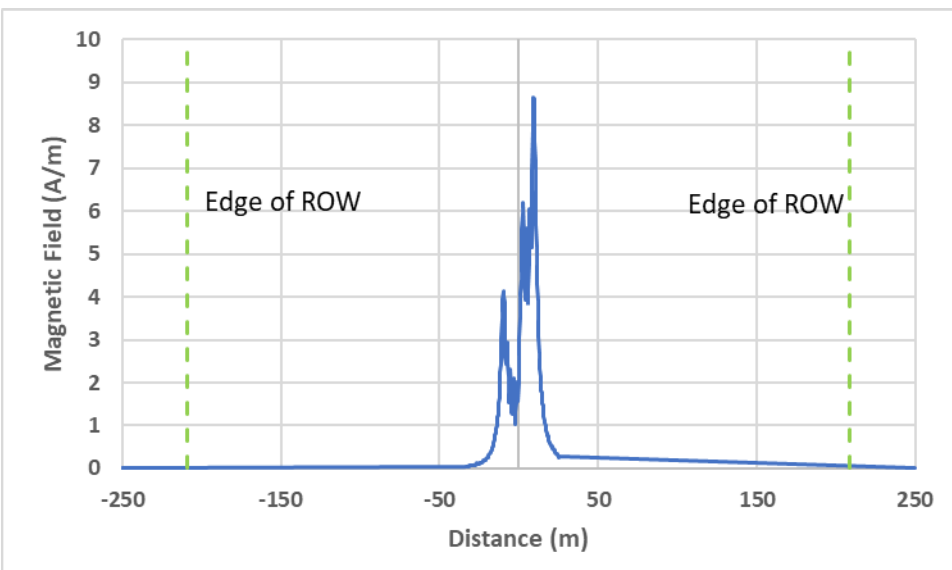

Figure 4-22 Magnetic Field Result of Case 10

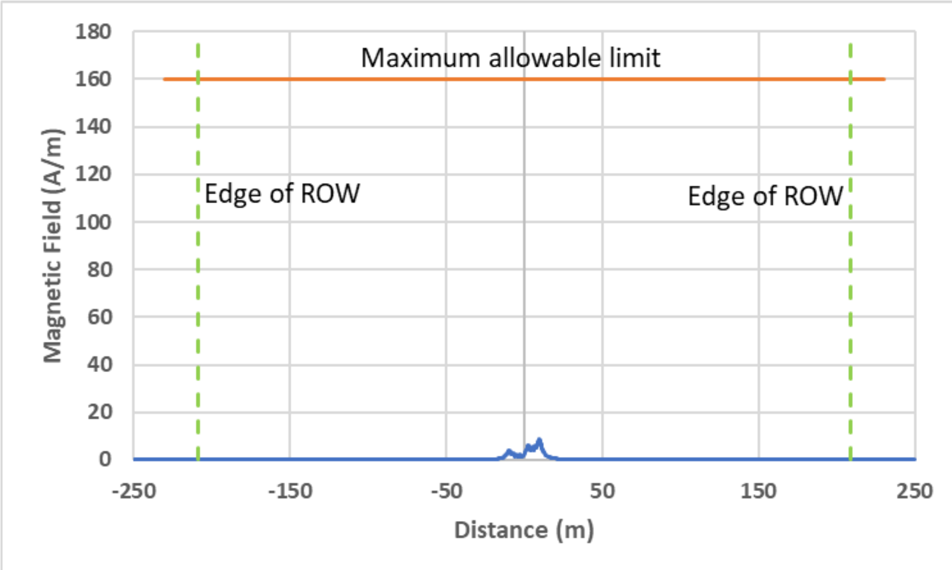

Figure 4-23 Magnetic Field Result of Case 10 with Maximum Allowable Limit

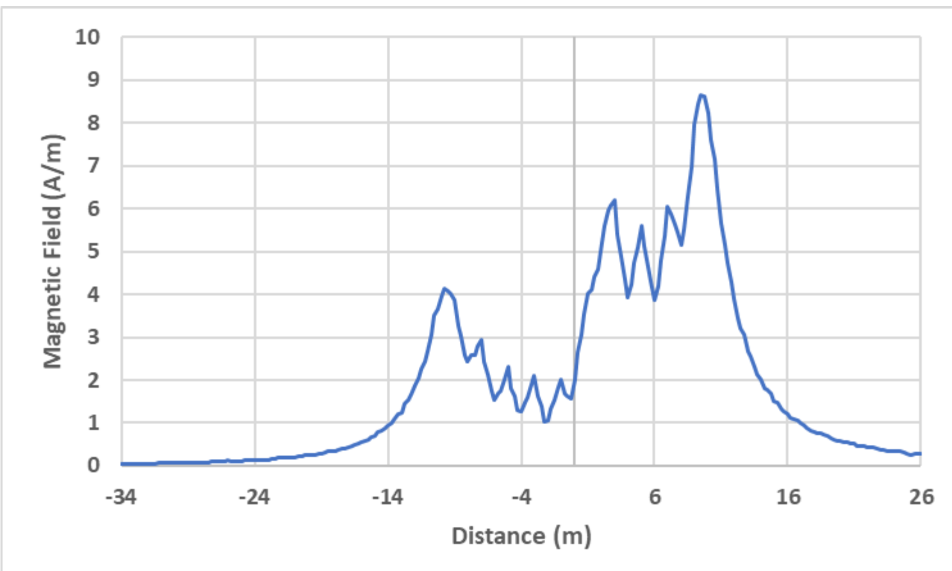

Figure 4-24 Zoomed Magnetic Field Result of Case 10

4.1.11 Case 11

Case 11 is for OSS where inter-array cable homeruns and offshore export cables are congregated (1200 mm^2 Al). OSS 1 (800 MW) - 6 inter-array cables (150 kV) & 4 offshore export cables (230 kV) including OSS interlink cables. EMF assessment at seabed.

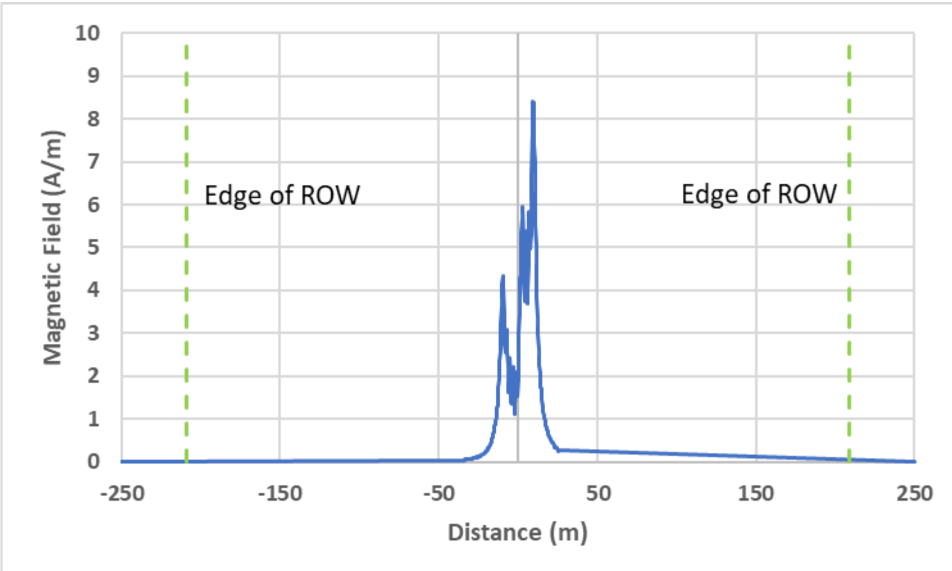

Figure 4-25 Magnetic Field Result of Case 11

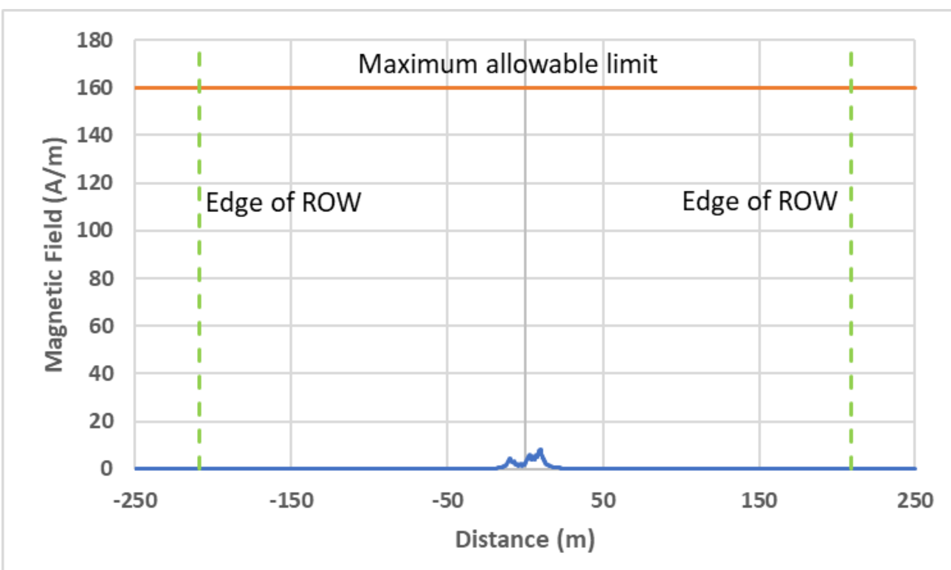

Figure 4-26 Magnetic Field Result of Case 11 with Maximum Limit

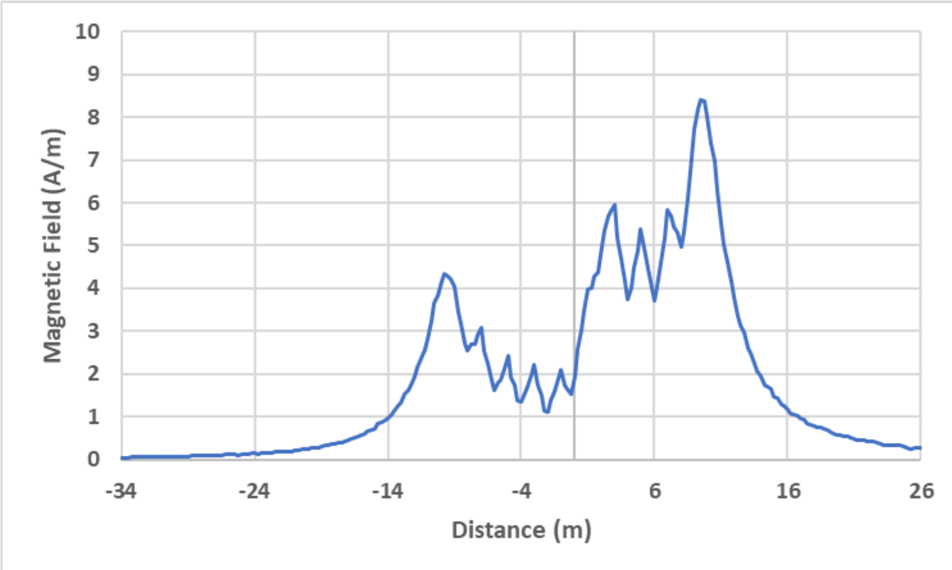

Figure 4-27 Zoomed Magnetic Field Result of Case 11

4.1.12 Case 12

Case 12 is for OSS where inter-array cable homeruns and offshore export cables are congregated (1200 mm^2 Al). OSS 1 (800 MW) - 6 inter-array cables (150 kV) & 4 offshore export cables (275 kV) including OSS interlink cables. EMF assessment at seabed.

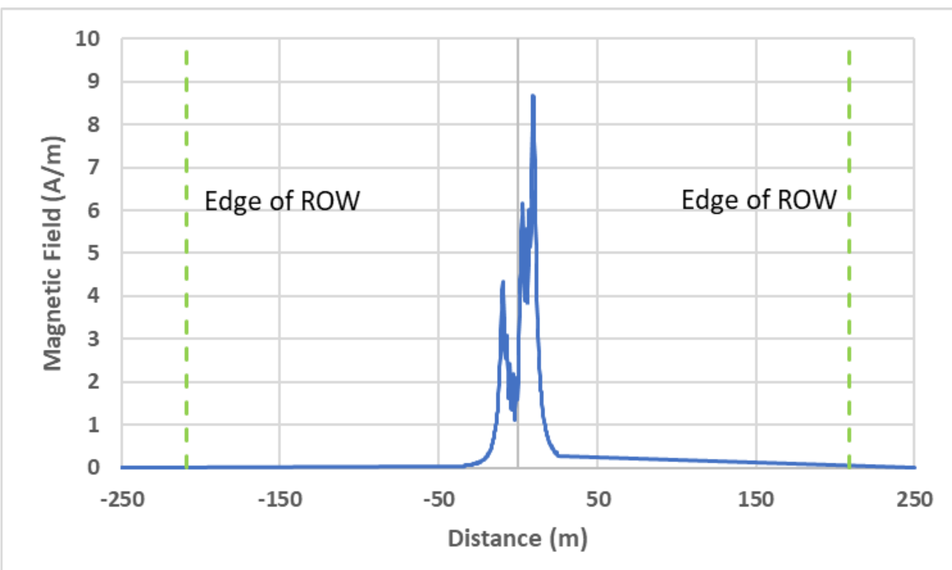

Figure 4-28 Magnetic Field Result of Case 12

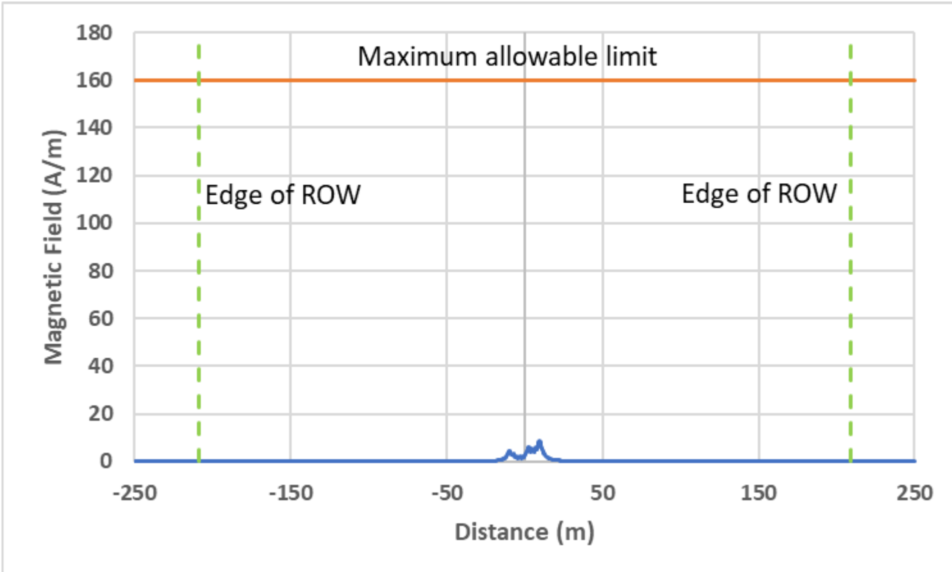

Figure 4-29 Magnetic Field Result of Case 12 with Maximum Limit

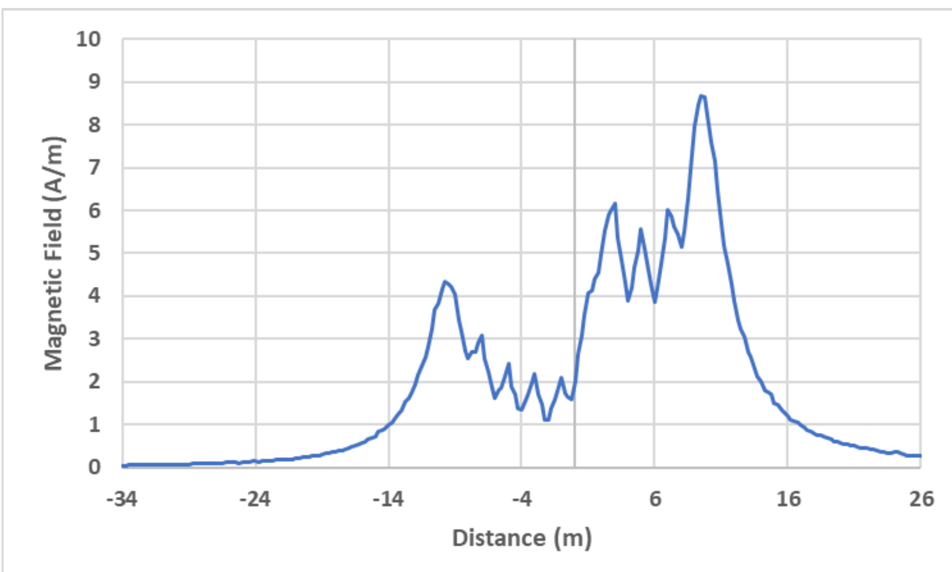

Figure 4-30 Zoomed Magnetic Field Result of Case 12

4.1.13 Case 13

Case 13 is for OSS where inter-array cable homeruns and offshore export cables are congregated (1200 mm^2 Al). OSS 2 (1200 MW) - 16 inter-array cables (66 kV) & 5 offshore export cables (230 kV) including OSS interlink cables. EMF assessment at seabed.

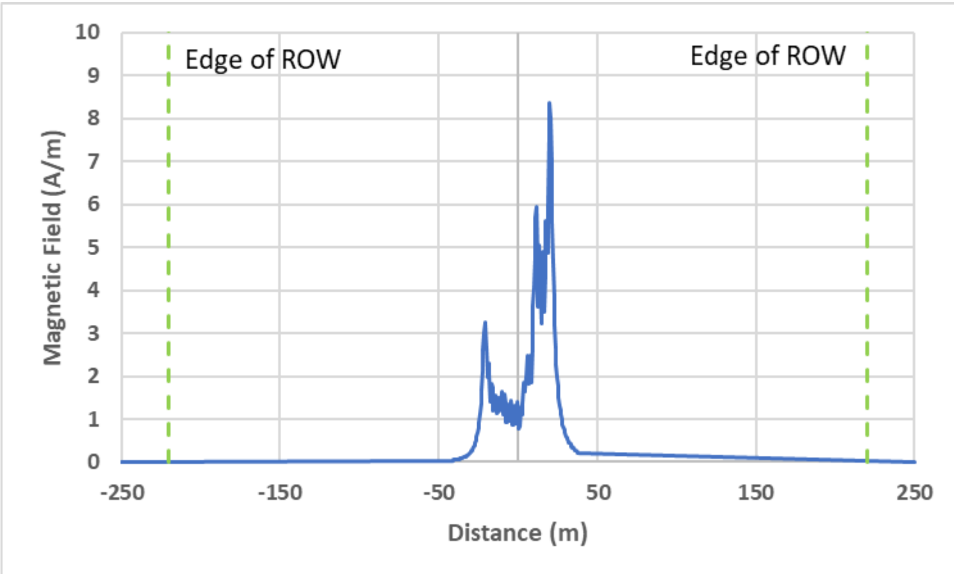

Figure 4-31 Magnetic Field Result of Case 13

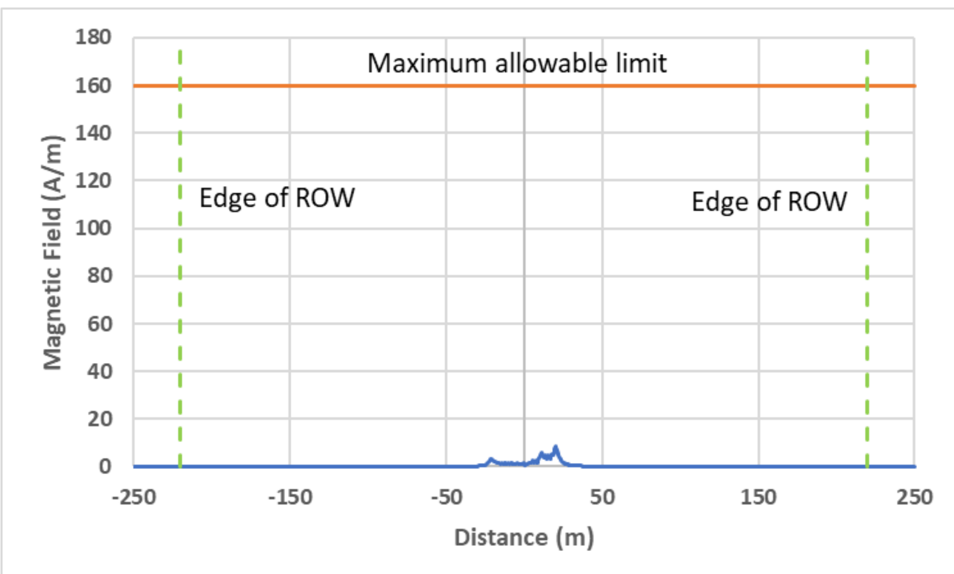

Figure 4-32 Magnetic Field Result of Case 13 with Maximum Limit

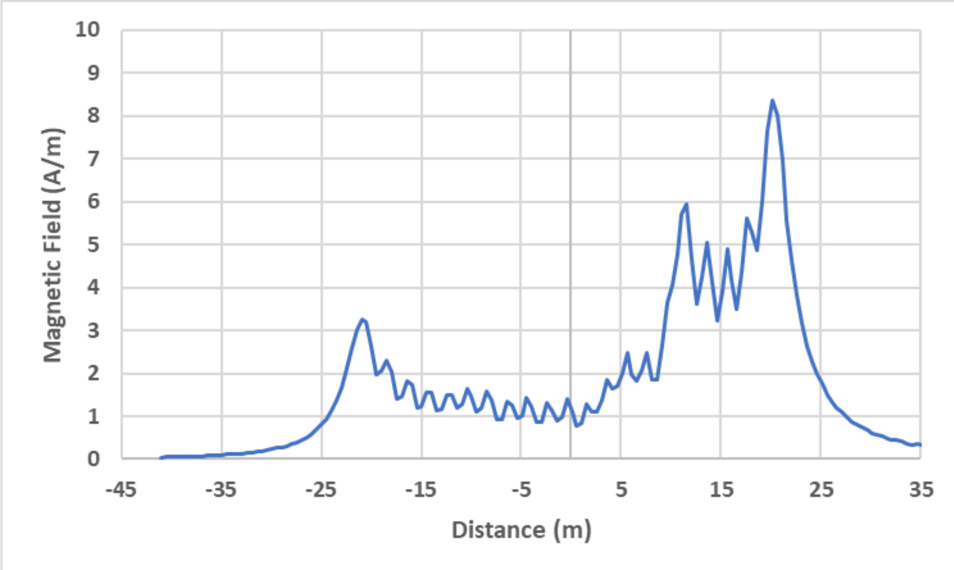

Figure 4-33 Zoomed Magnetic Field Result of Case 13

4.1.14 Case 14

Case 14 is for OSS where inter-array cable homeruns and offshore export cables are congregated (1200 mm^2 Al). OSS 2 (1200 MW) - 16 inter-array cables (66 kV) & 5 offshore export cables (275 kV) including OSS interlink cables. EMF assessment at seabed.

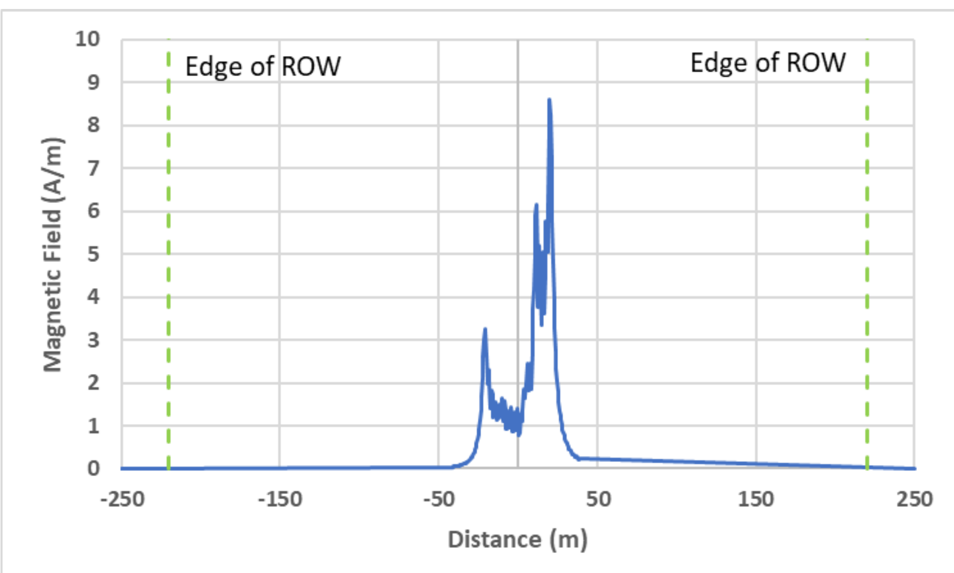

Figure 4-34 Magnetic Field Result of Case 14

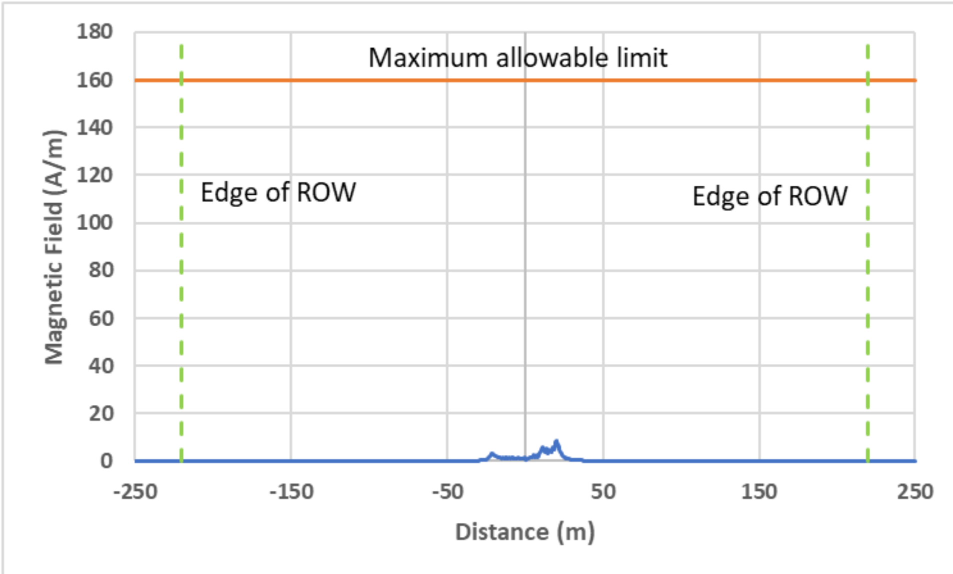

Figure 4-35 Magnetic Field Result of Case 14 with Maximum Limit

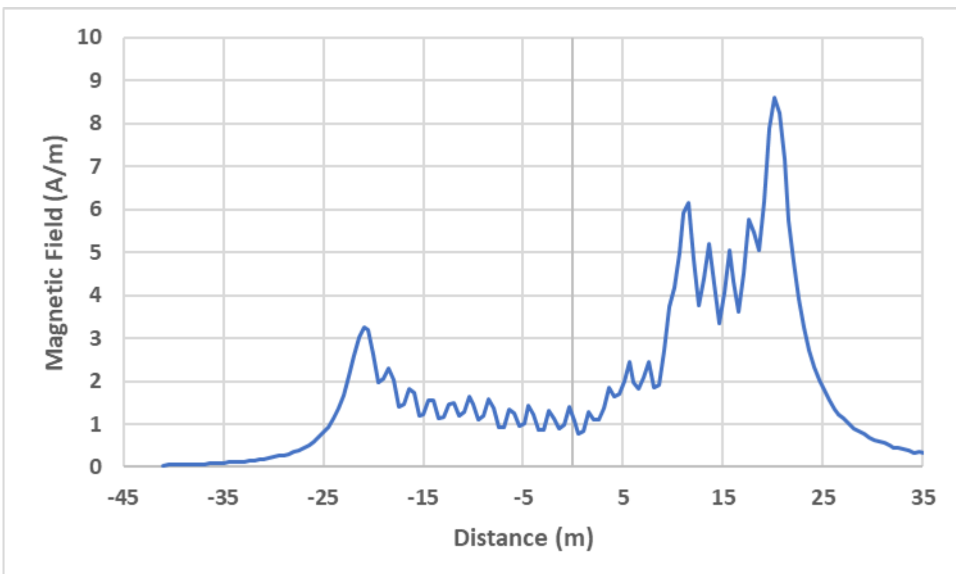

Figure 4-36 Zoomed Magnetic Field Result of Case 14

4.1.15 Case 15

Case 15 is for OSS where inter-array cable homeruns and offshore export cables are congregated (1200 mm^2 Al). OSS 2 (1200 MW) - 8 inter-array cables (132 kV) & 5 offshore export cables (230 kV) including OSS interlink cables. EMF assessment at seabed.

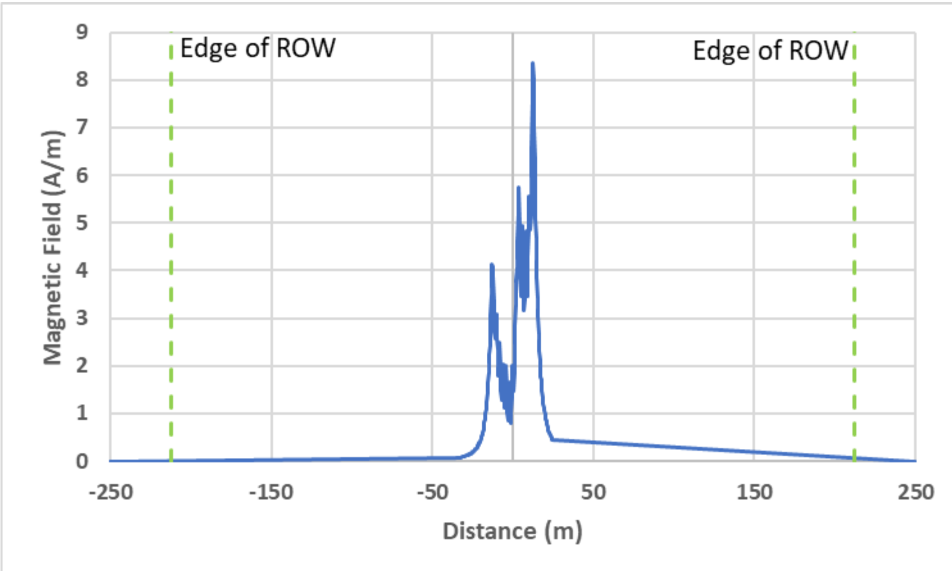

Figure 4-37 Magnetic Field Result of Case 15

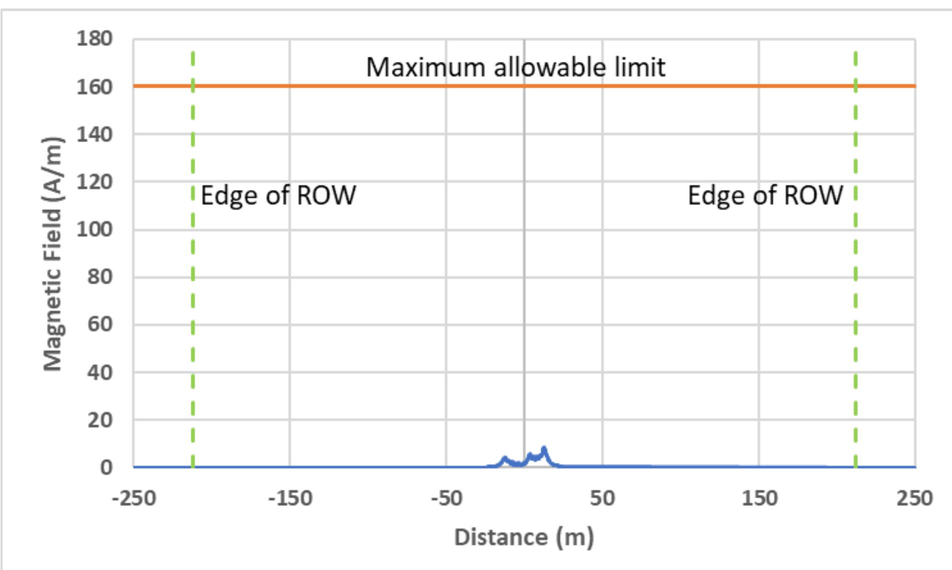

Figure 4-38 Magnetic Field Result of Case 15 with Maximum Limit

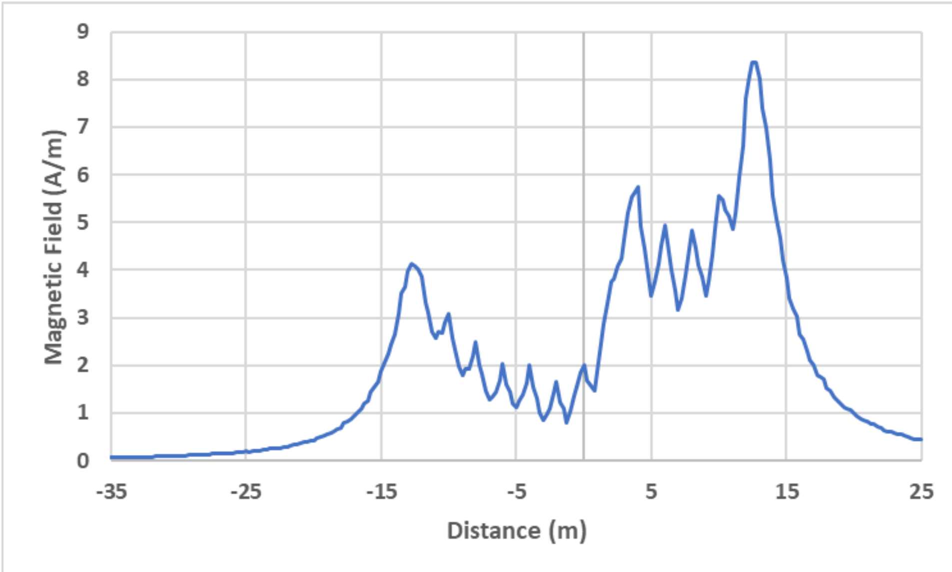

Figure 4-39 Zoomed Magnetic Field Result of Case 15

4.1.16 Case 16

Case 16 is for OSS where inter-array cable homeruns and offshore export cables are congregated (1200 mm^2 Al). OSS 2 (1200 MW) - 8 inter-array cables (132 kV) & 5 offshore export cables (275 kV) including OSS interlink cables. EMF assessment at seabed.

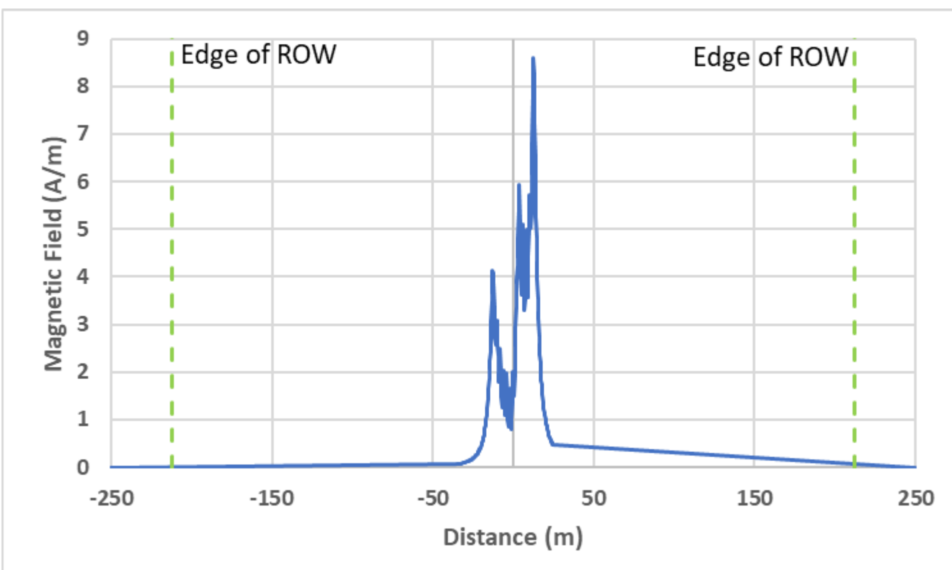

Figure 4-40 Magnetic Field Result of Case 16

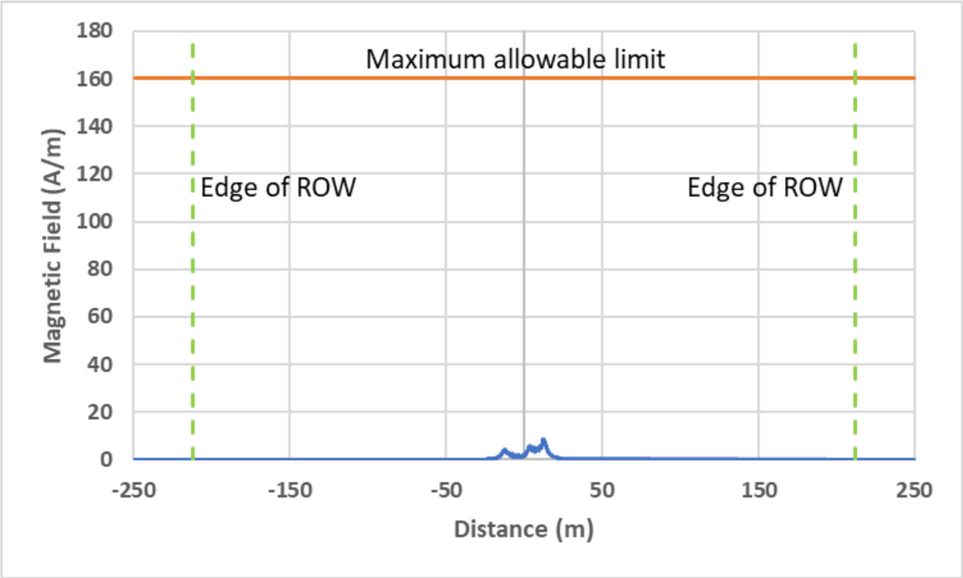

Figure 4-41 Magnetic Field Result of Case 16 with Maximum Limit

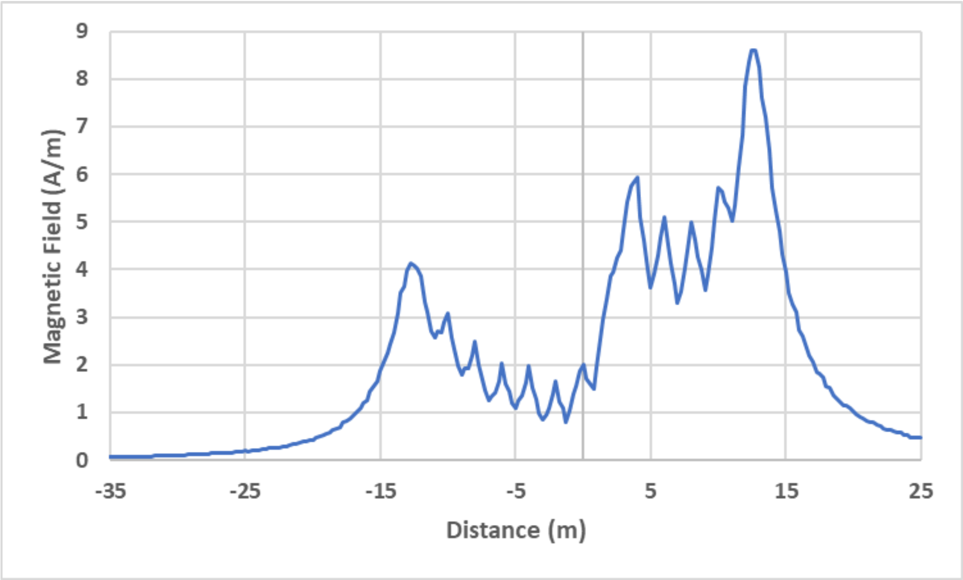

Figure 4-42 Zoomed Magnetic Field Result of Case 16

4.1.17 Case 17

Case 17 is for OSS where inter-array cable homeruns and offshore export cables are congregated (1200 mm^2 Al). OSS 2 (1200 MW) - 8 inter-array cables (150 kV) & 5 offshore export cables (230 kV) including OSS interlink cables. EMF assessment at seabed.

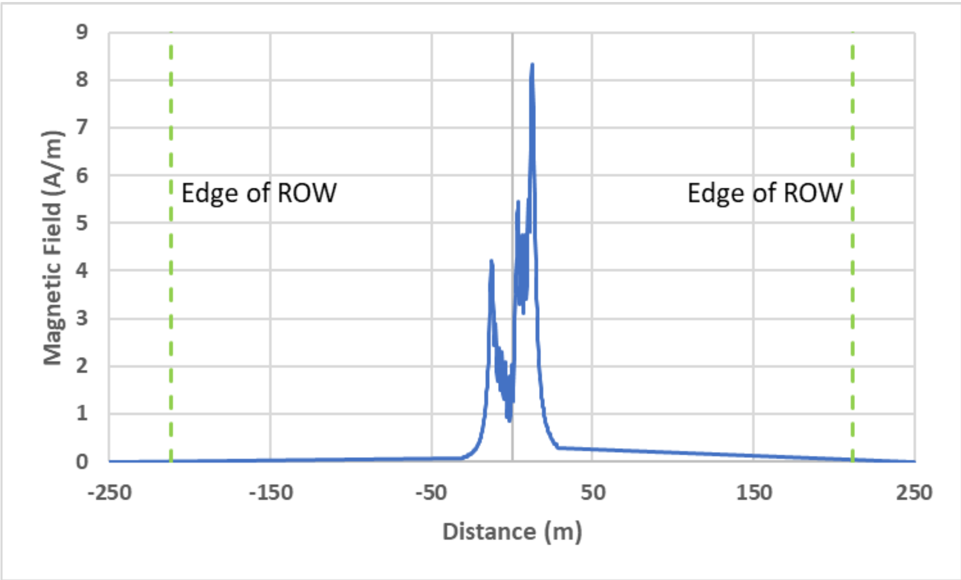

Figure 4-43 Magnetic Field Result of Case 17

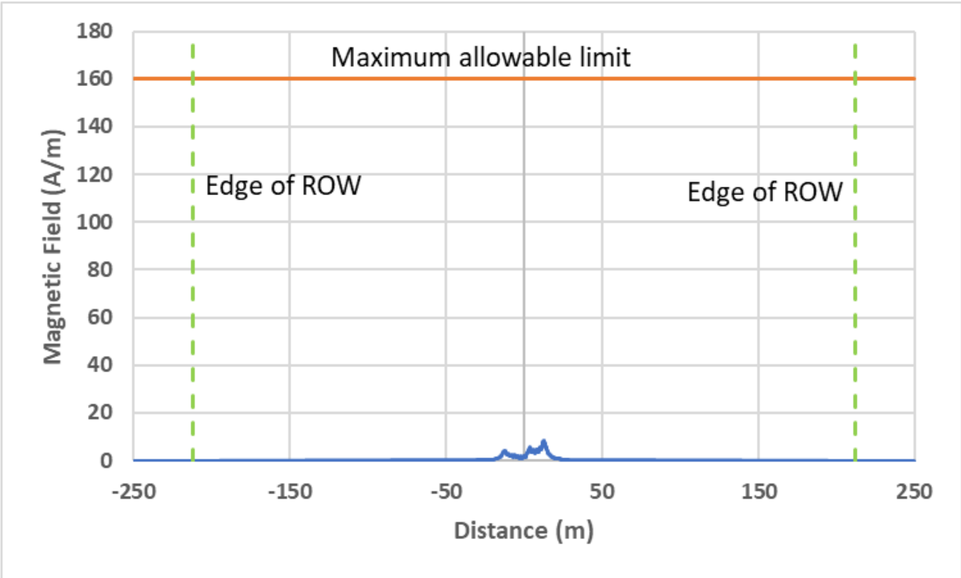

Figure 4-44 Magnetic Field Result of Case 17 with Maximum Limit

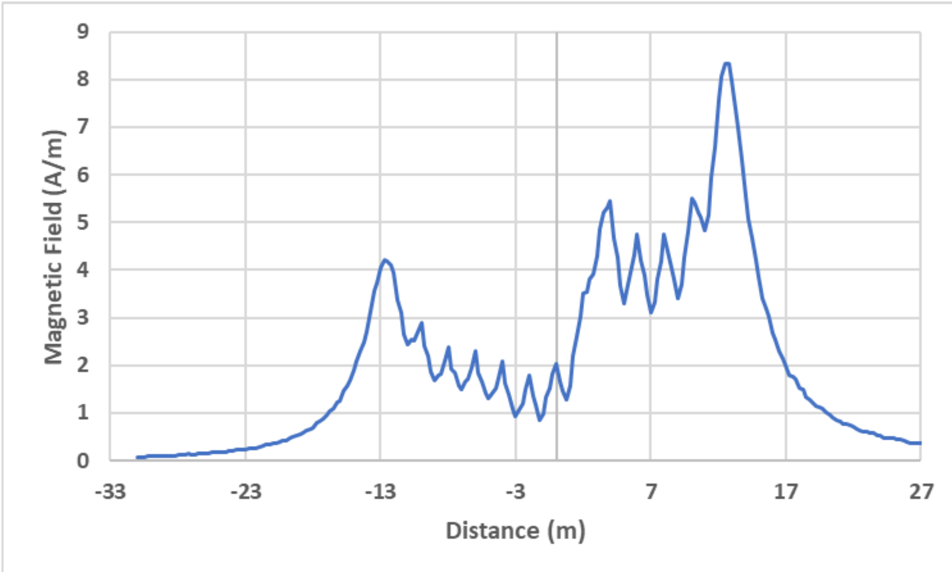

Figure 4-45 Zoomed Magnetic Field Result of Case 17

4.1.18 Case 18

Case 18 is for OSS where inter-array cable homeruns and offshore export cables are congregated (1200 mm^2 Al). OSS 2 (1200 MW) - 8 inter-array cables (150 kV) & 5 offshore export cables (275 kV) including OSS interlink cables. EMF assessment at seabed.

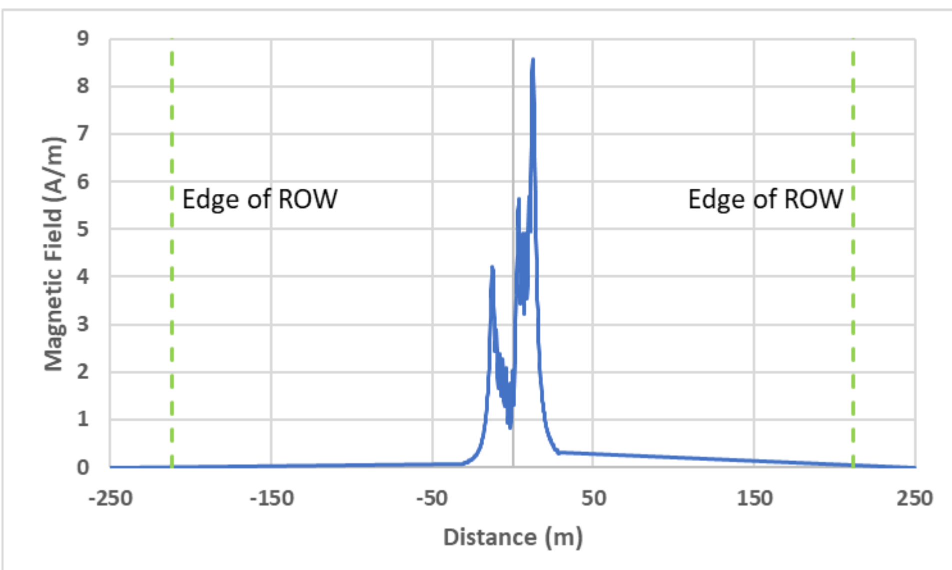

Figure 4-46 Magnetic Field Result of Case 18

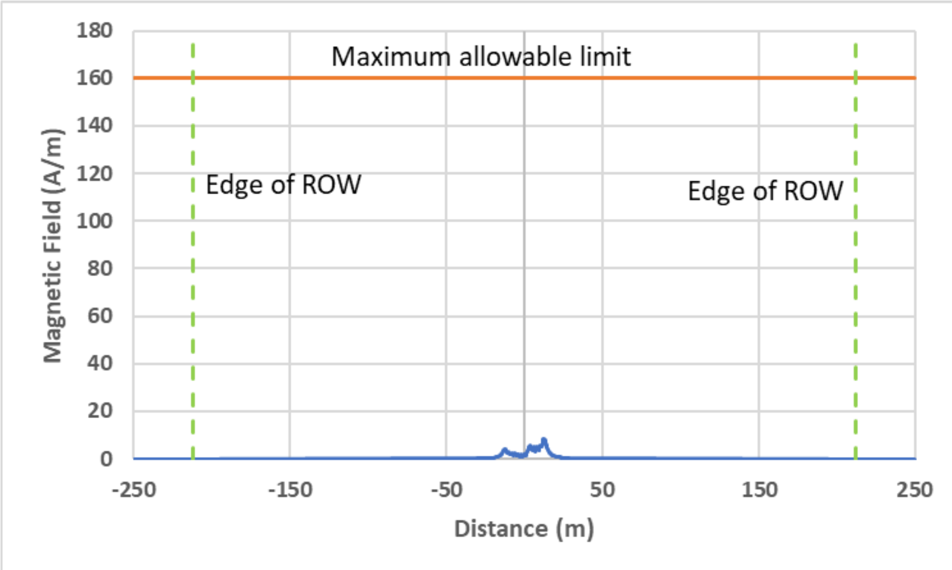

Figure 4-47 Magnetic Field Result of Case 18 with Maximum Limit

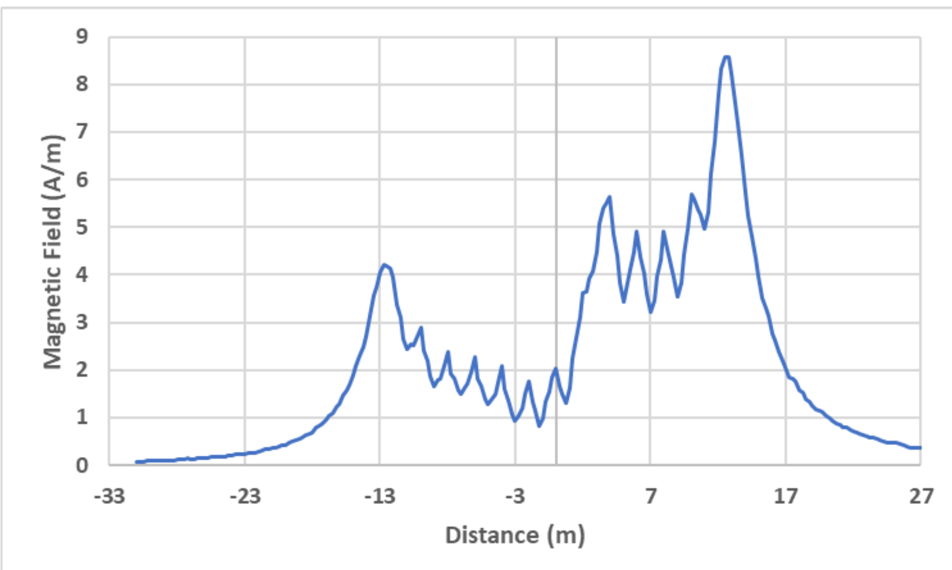

Figure 4-48 Zoomed Magnetic Field Result of Case 18

4.1.19 Case 19

Case 19 relates to alternative substation in New York or New Jersey, HVDC option (1200 mm^2 Al). OSS 3 (1200 MW) - 16 inter-array cables (66 kV) & One positive and One negative HVDC offshore export cables (320 kV or 525 kV). EMF assessment at seabed

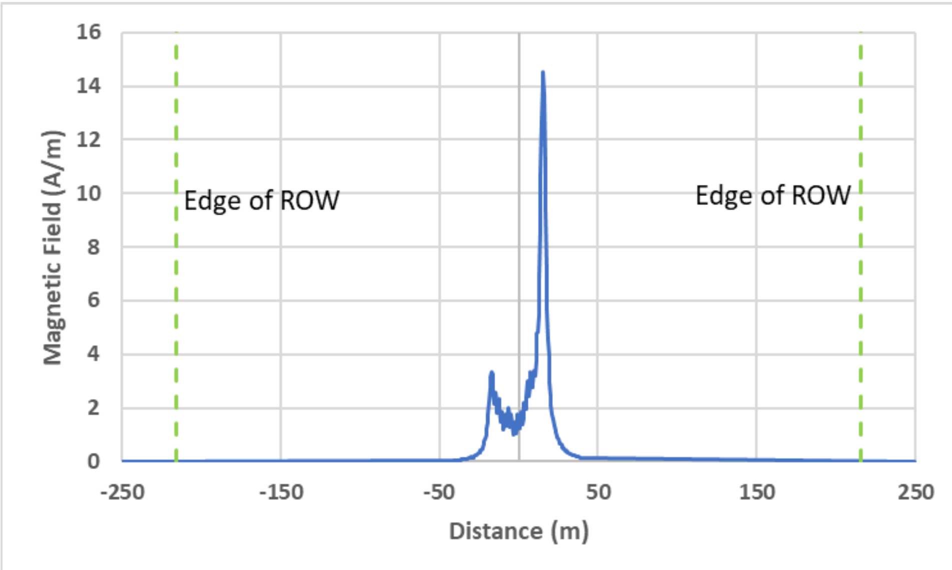

Figure 4-49 Magnetic Field Result of Case 19

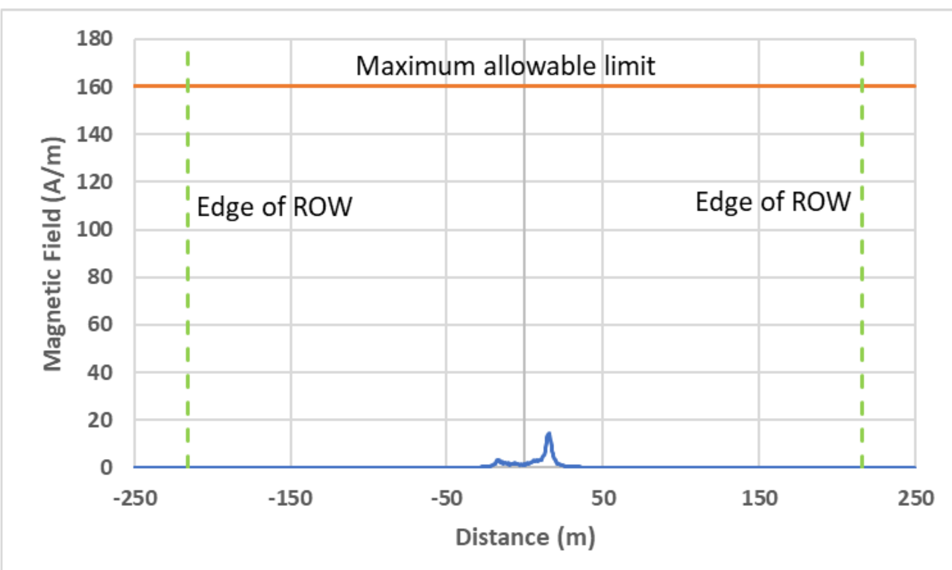

Figure 4-50 Magnetic Field Result of Case 19 with Maximum Limit

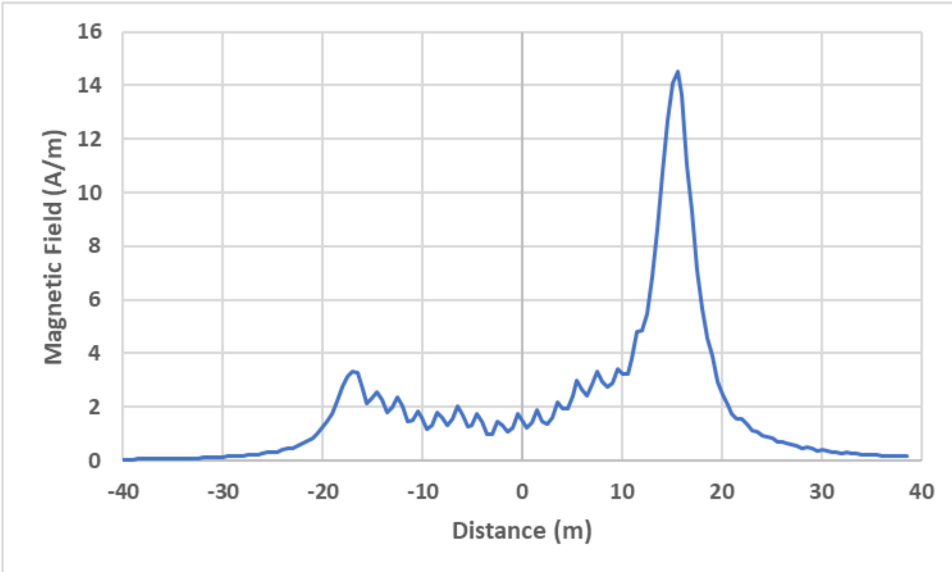

Figure 4-51 Zoomed Magnetic Field Result of Case 19

4.1.20 Case 20

Case 20 relates to alternative substation in New York or New Jersey, HVDC option (1200 mm^2 Al). OSS 3 (1200 MW) - 16 inter-array cables (66 kV) & One positive and One negative HVDC offshore export cables (525 kV). EMF assessment at seabed.

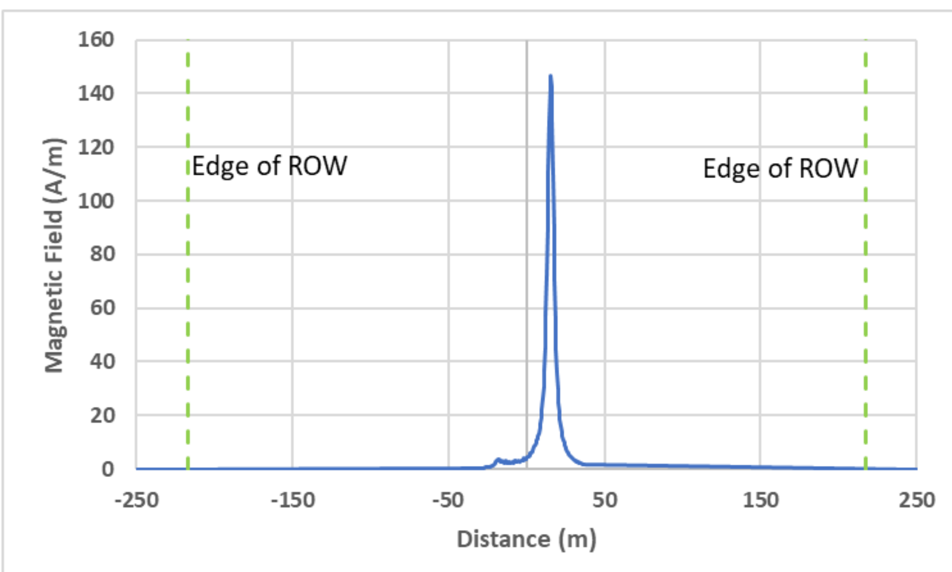

Figure 4-52 Magnetic Field Result of Case 20

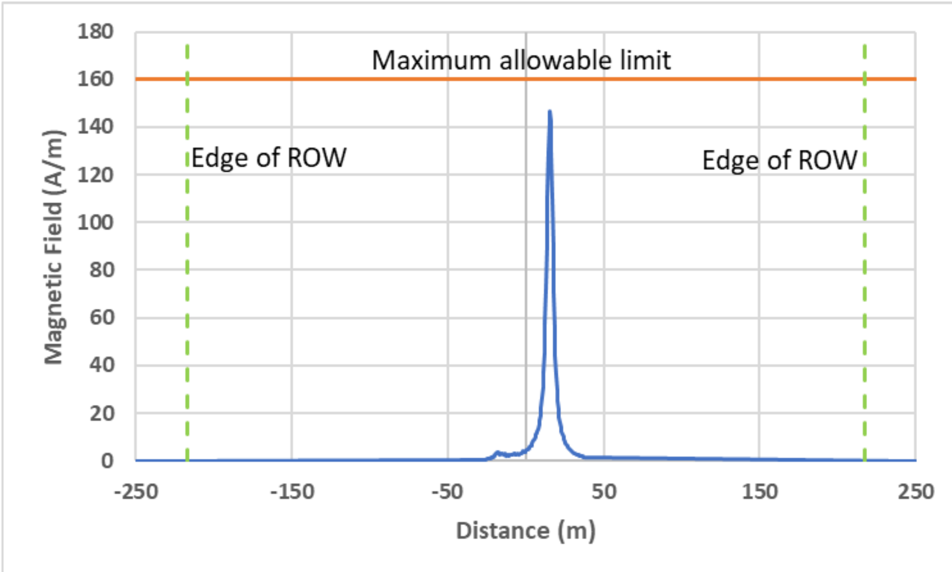

Figure 4-53 Magnetic Field Result of Case 20 with Maximum Limit

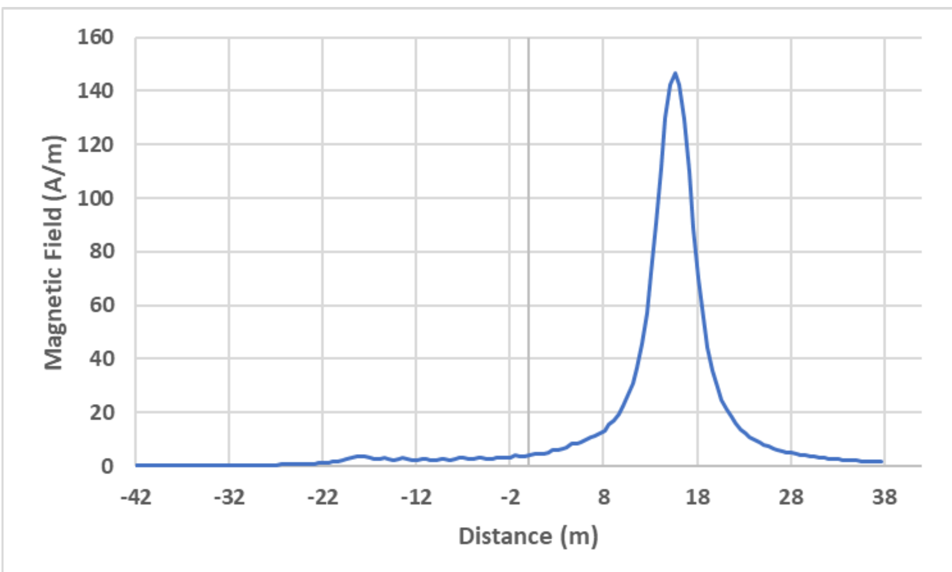

Figure 4-54 Zoomed Magnetic Field Result of Case 20

4.1.21 Case 21

Case 21 relates to alternative substation in New York or New Jersey, HVDC option (1200 mm^2 Al). OSS 3 (1200 MW) - 8 inter-array cables (132 kV) & One positive and One negative HVDC offshore export cables (320 kV or 525 kV). EMF assessment at seabed.

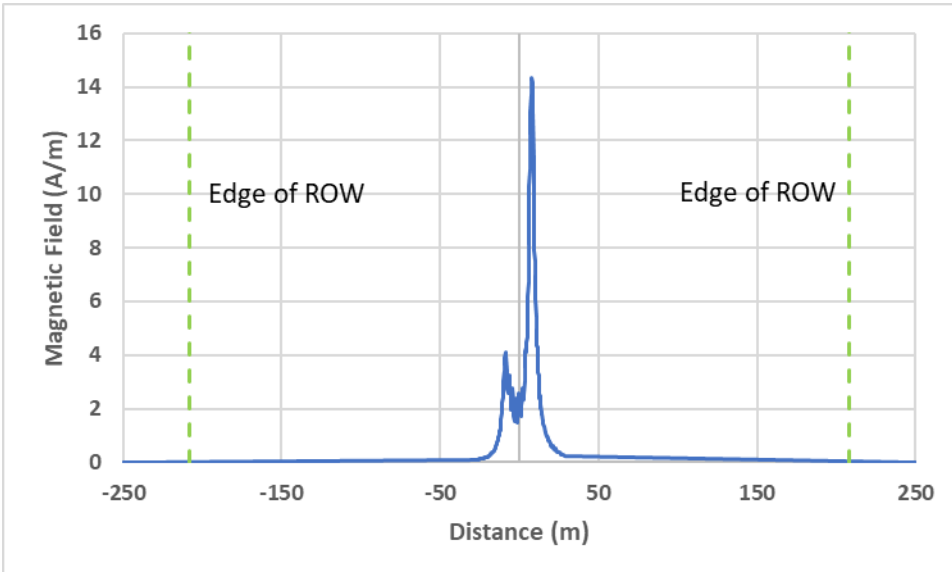

Figure 4-55 Magnetic Field Result of Case 21

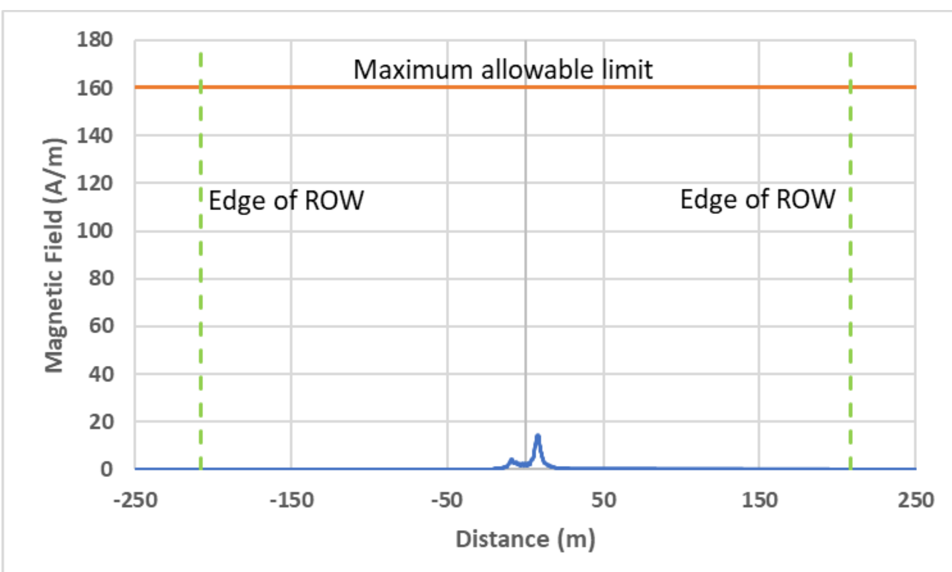

Figure 4-56 Magnetic Field Result of Case 21 with Maximum Limit

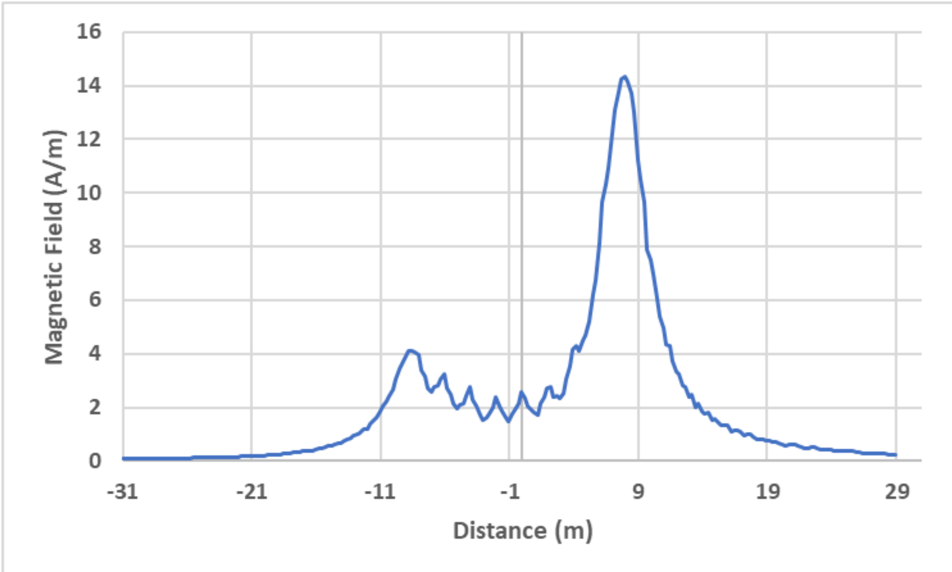

Figure 4-57 Zoomed Magnetic Field Result of Case 21

4.1.22 Case 22

Case 22 relates to alternative substation in New York or New Jersey, HVDC option (1200 mm^2 Al). OSS 3 (1200 MW) - 8 inter-array cables (132 kV) & One positive and One negative HVDC offshore export cables (525 kV). EMF assessment at seabed.

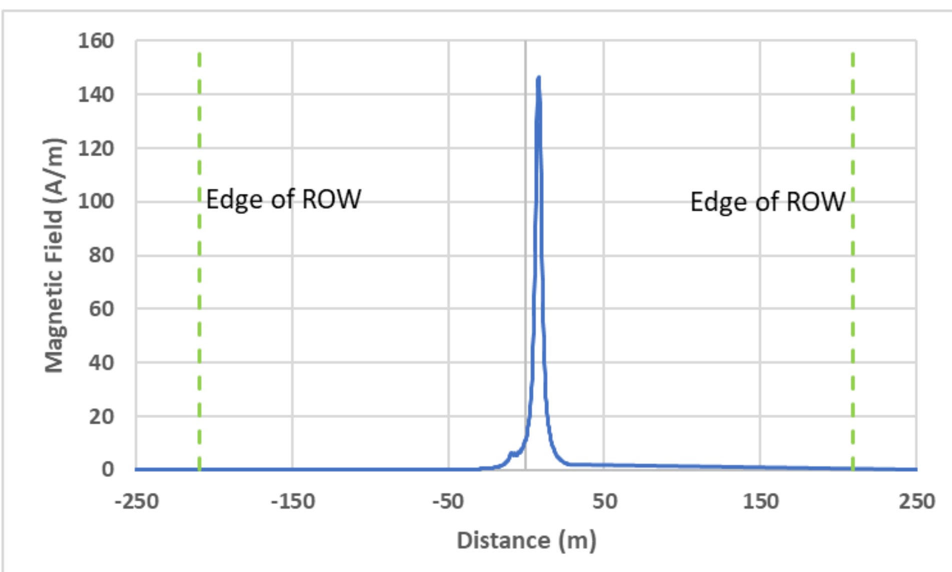

Figure 4-58 Magnetic Field Result of Case 22

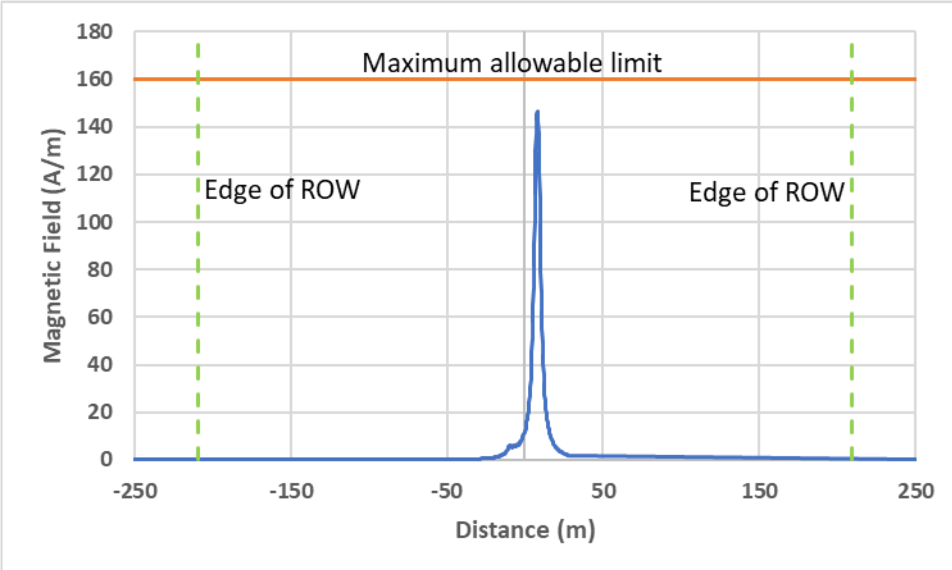

Figure 4-59 Magnetic Field Result of Case 22 with Maximum Limit

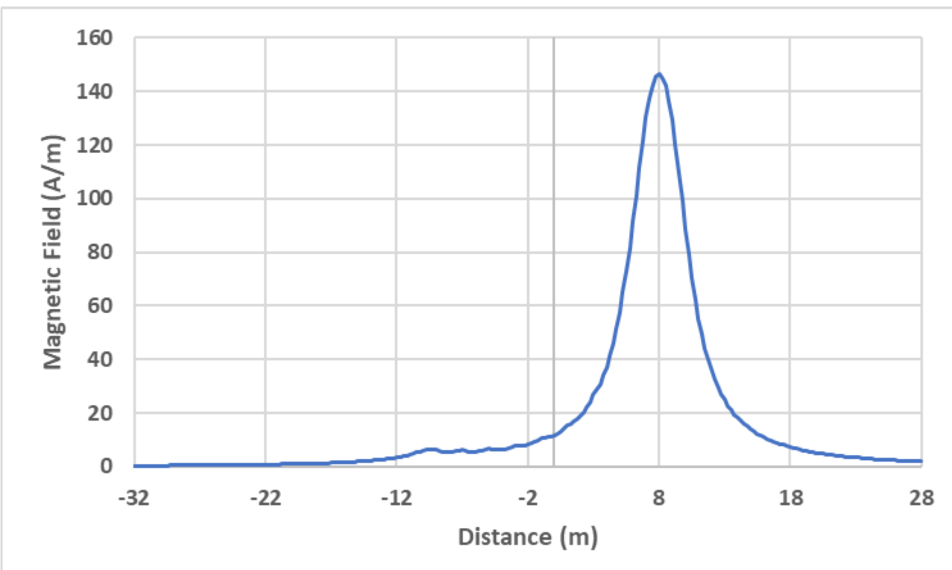

Figure 4-60 Zoomed Magnetic Field Result of Case 22

4.1.23 Case 23

Case 23 relates to alternative substation in New York or New Jersey, HVDC option (1200 mm^2 Al). OSS 3 (1200 MW) - 8 inter-array cables (150 kV) & One positive and One negative HVDC offshore export cables (320 kV or 525 kV). EMF assessment at seabed.

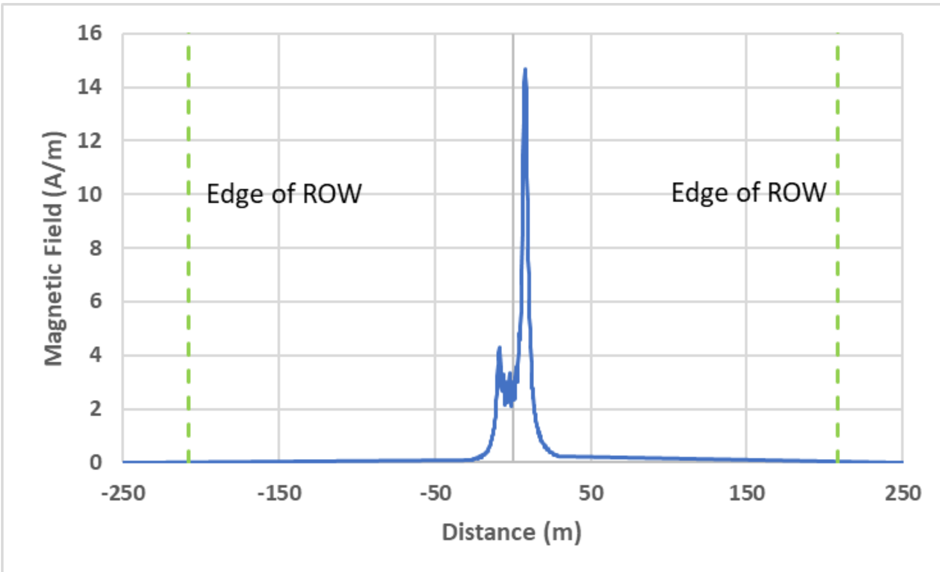

Figure 4-61 Magnetic Field Result of Case 23

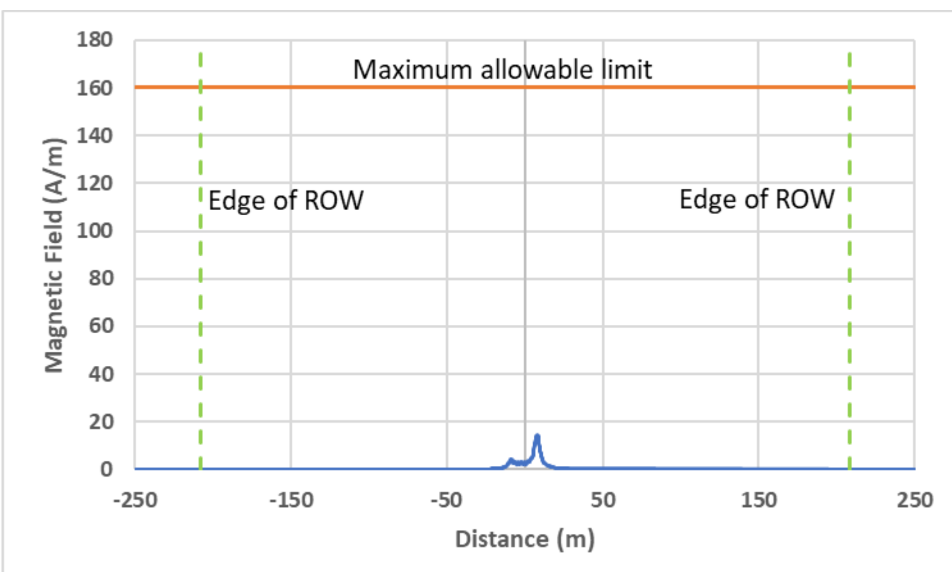

Figure 4-62 Magnetic Field Result of Case 23 with Maximum Limit

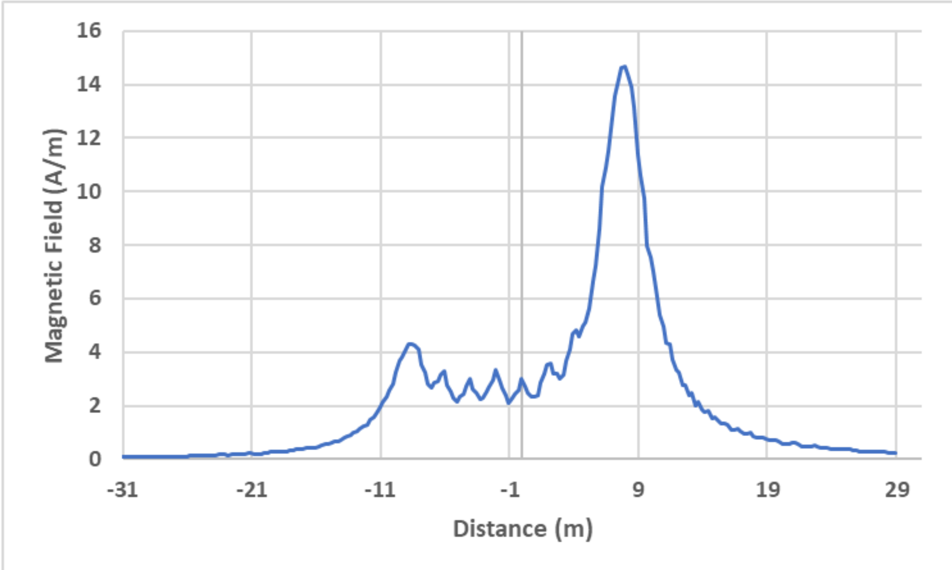

Figure 4-63 Zoomed Magnetic Field Result of Case 23

4.1.24 Case 24

Case 24 relates to alternative substation in New York or New Jersey, HVDC option (1200 mm^2 Al). OSS 3 (1200 MW) - 8 inter-array cables (150 kV) & One positive and One negative HVDC offshore export cables (525 kV). EMF assessment at seabed.

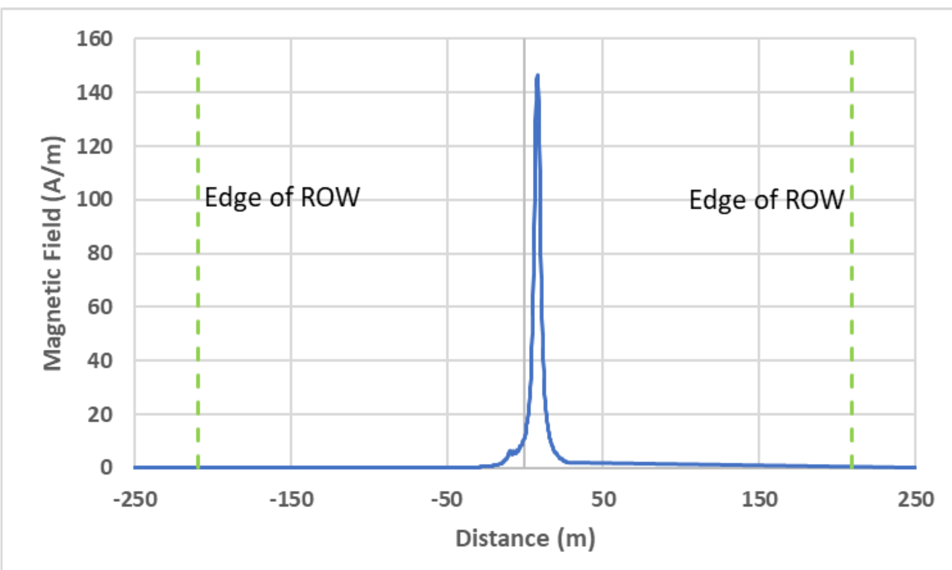

Figure 4-64 Magnetic Field Result of Case 24

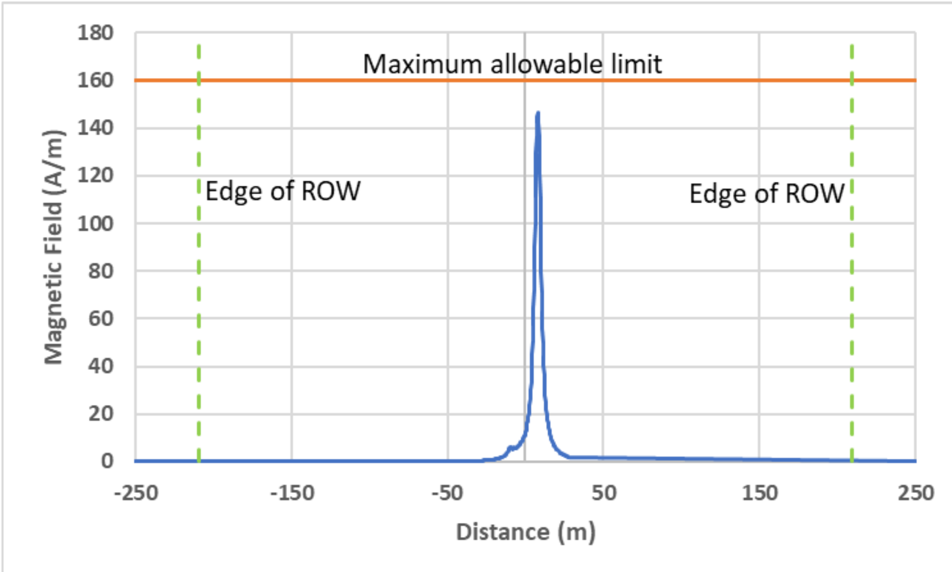

Figure 4-65 Magnetic Field Result of Case 24 with Maximum Limit

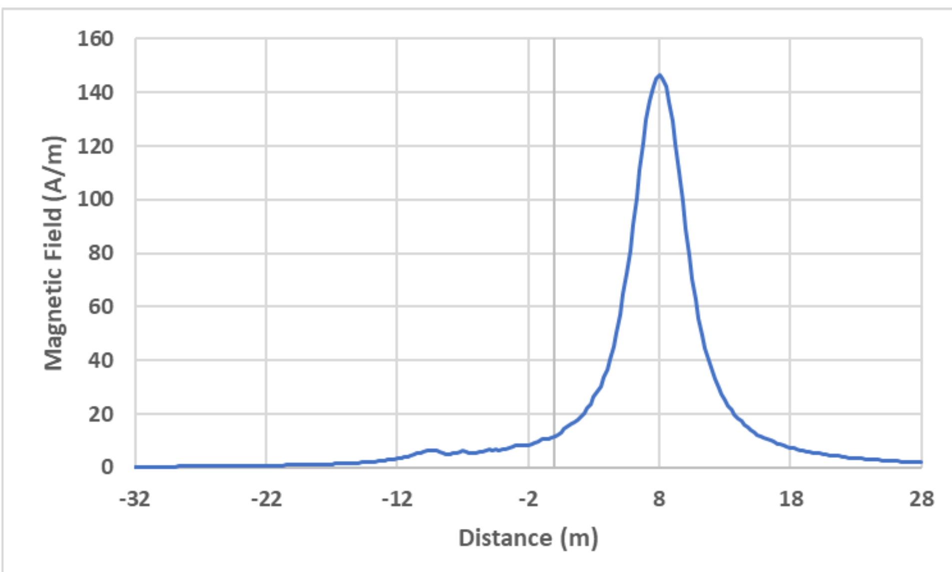

Figure 4-66 Zoomed Magnetic Field Result of Case 24

4.1.25 Case 25

Case 25 relates to HVAC Offshore export cable (2000 mm^2 Cu). Landfall Horizontal Direction Drill (HDD) profile - 3 offshore export cables (230 kV) NY Route. EMF assessment at Seabed.

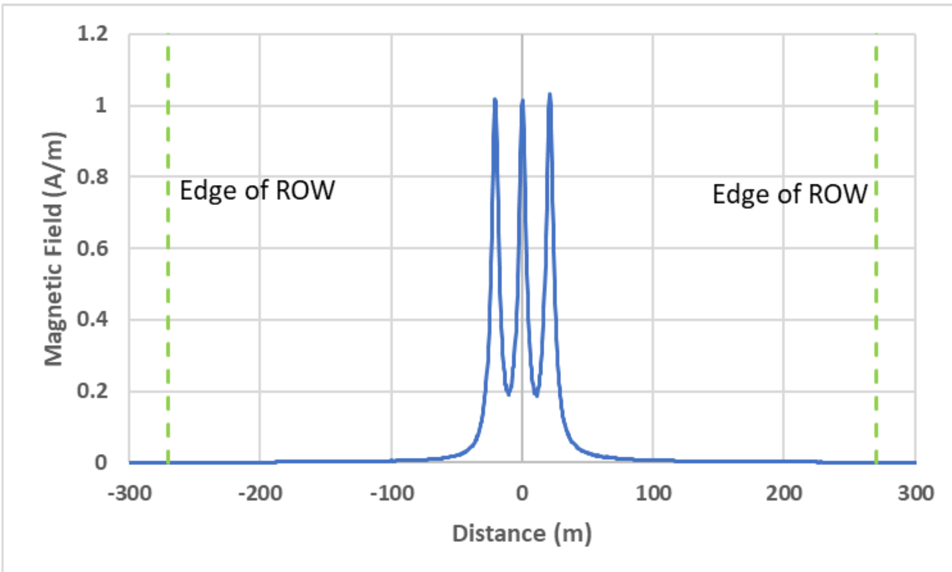

Figure 4-67 Magnetic Field Result of Case 25

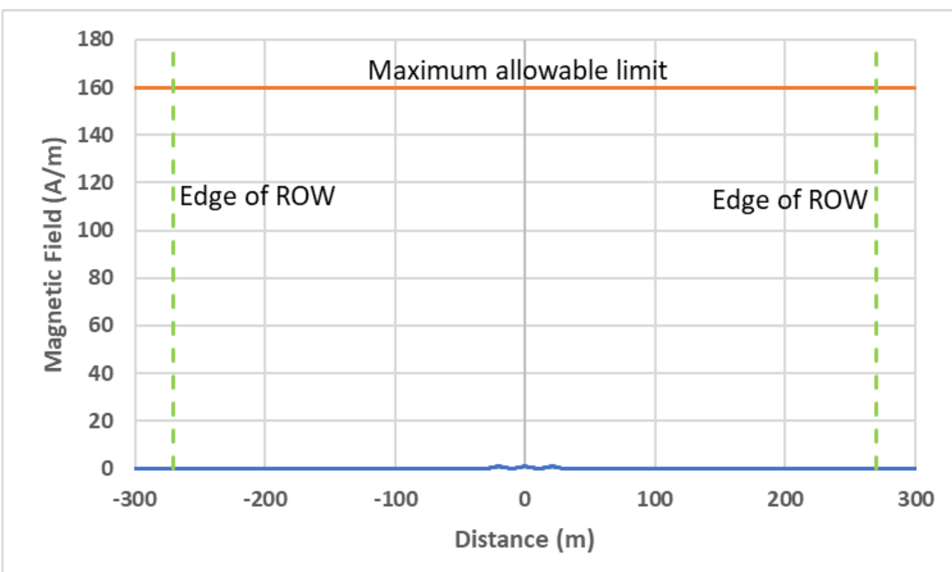

Figure 4-68 Magnetic Field Result of Case 25 with Maximum Limit

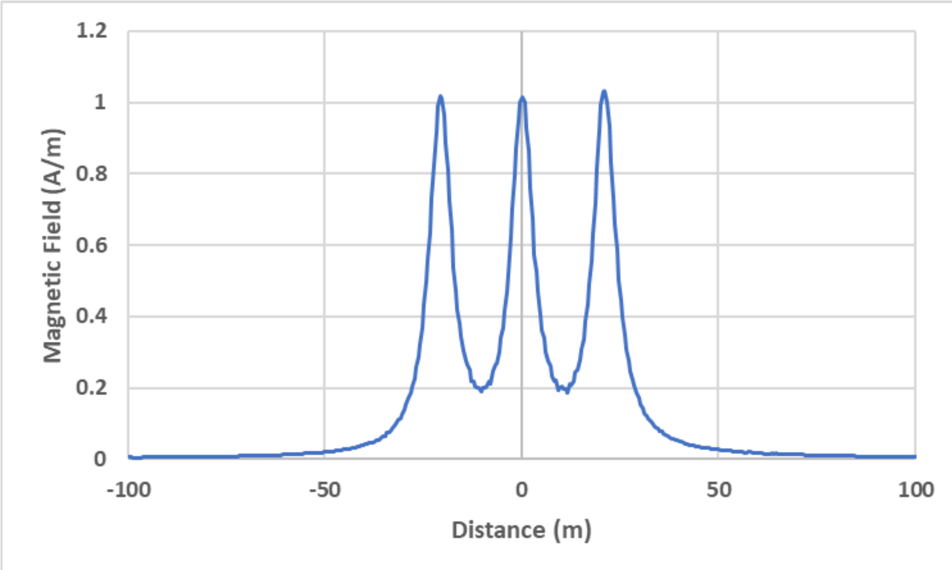

Figure 4-69 Zoomed Magnetic Field Result of Case 25

4.1.26 Case 26

Case 26 relates to HVAC Offshore export cable (2000 mm^2 Cu). Buried in seabed (6' from Seabed) - 3 offshore export cables (230 kV) NY Route. EMF assessment at seabed.

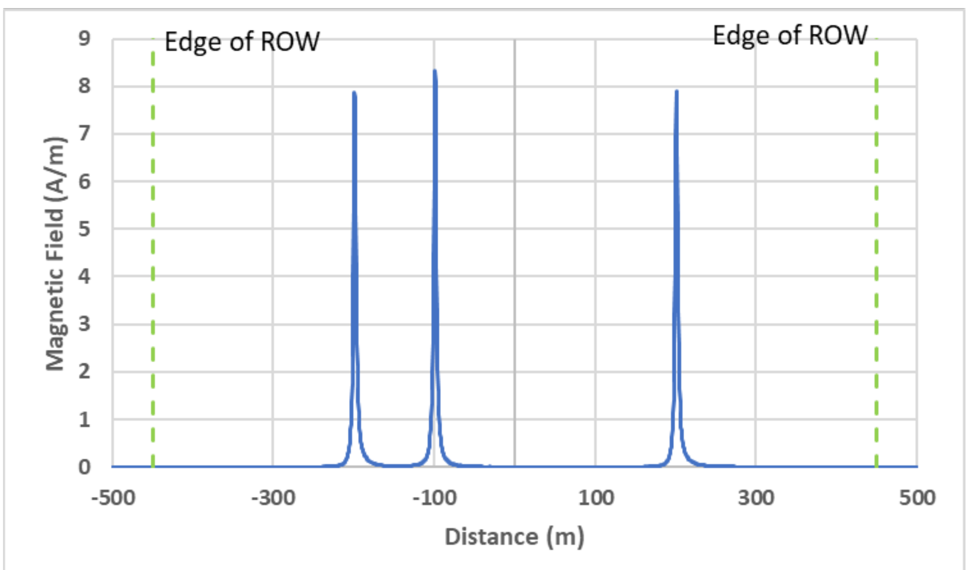

Figure 4-70 Magnetic Field Result of Case 26

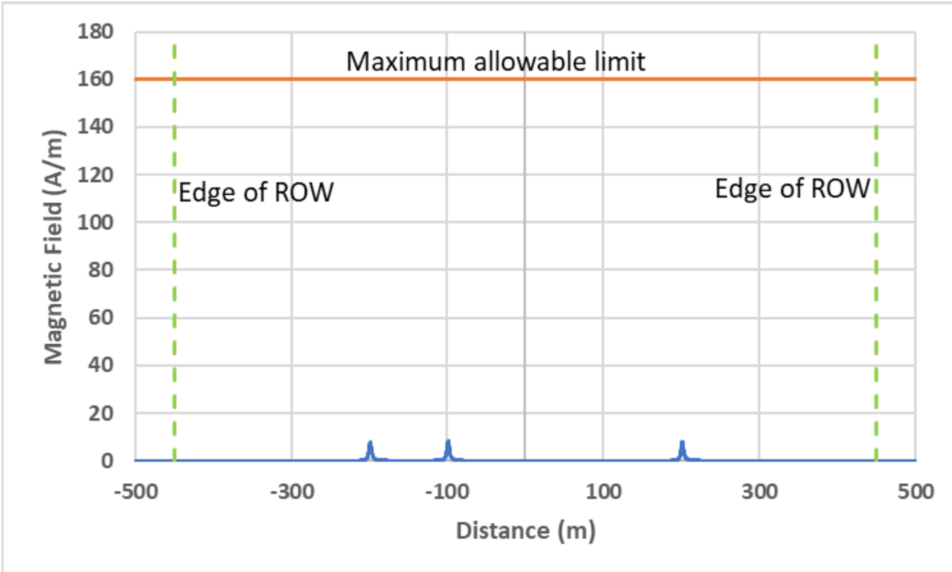

Figure 4-71 Magnetic Field Result of Case 26 with Maximum Limit

4.1.27 Case 27

Case 27 relates to HVAC Offshore export cable (2000 mm[2] Cu). Landfall HDD profile - 3 offshore export cables (275 kV) NY Route. EMF assessment at seabed.

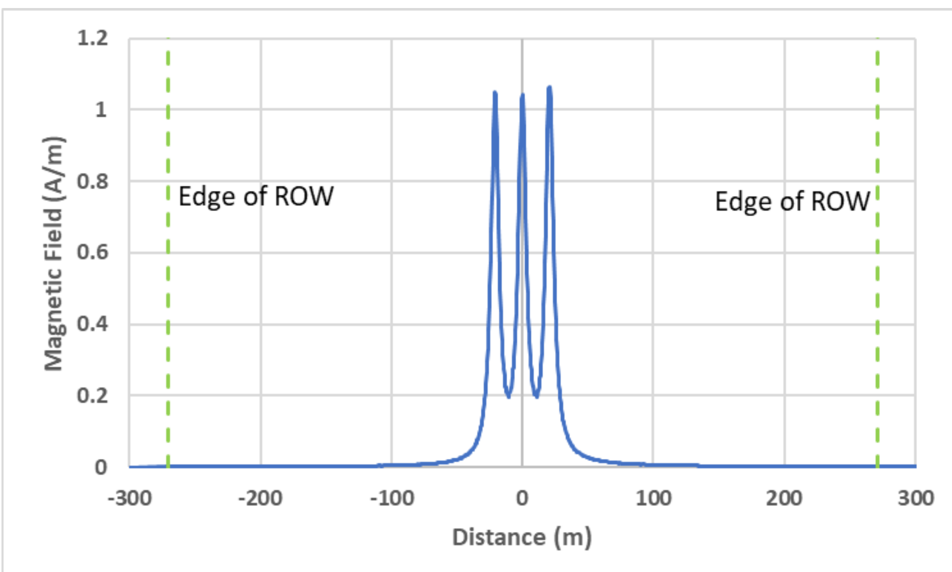

Figure 4-72 Magnetic Field Result of Case 27

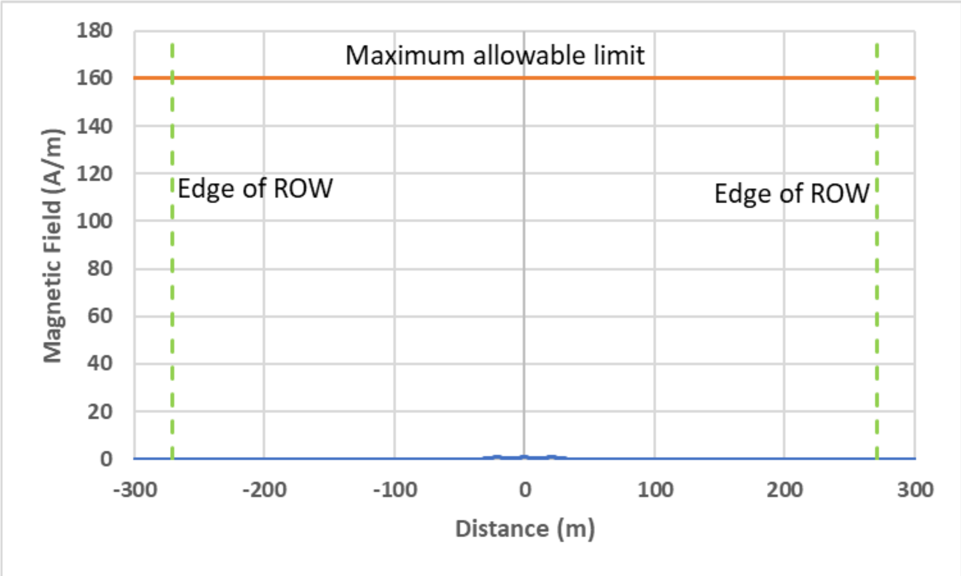

Figure 4-73 Magnetic Field Result of Case 27 with Maximum Limit

4.1.28 Case 28

Case 28 relates to HVAC Offshore export cable, Offshore (2000 mm^2 Cu). Buried in seabed (6' from Seabed) - 3 offshore export cables (275 kV) NY Route. EMF assessment at seabed.

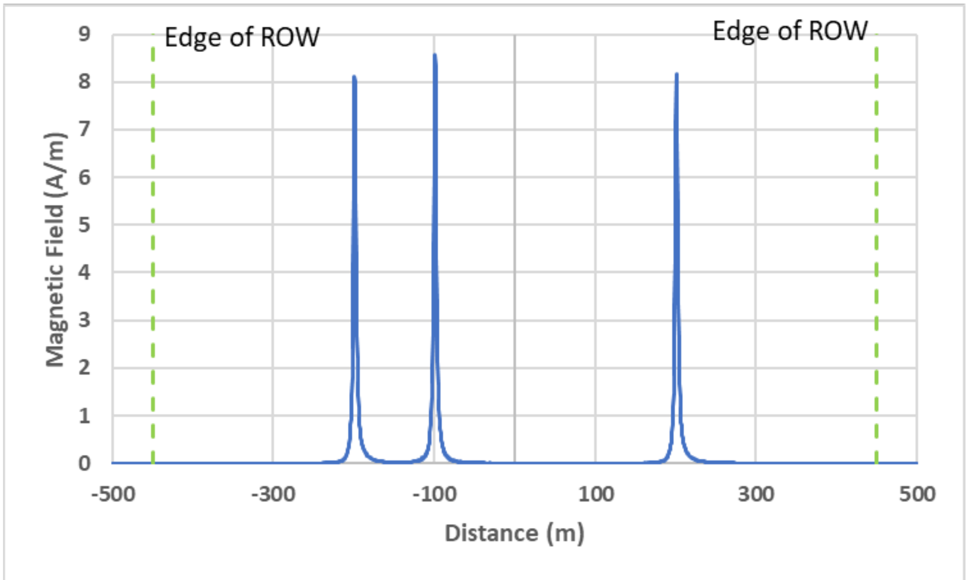

Figure 4-74 Magnetic Field Result of Case 28

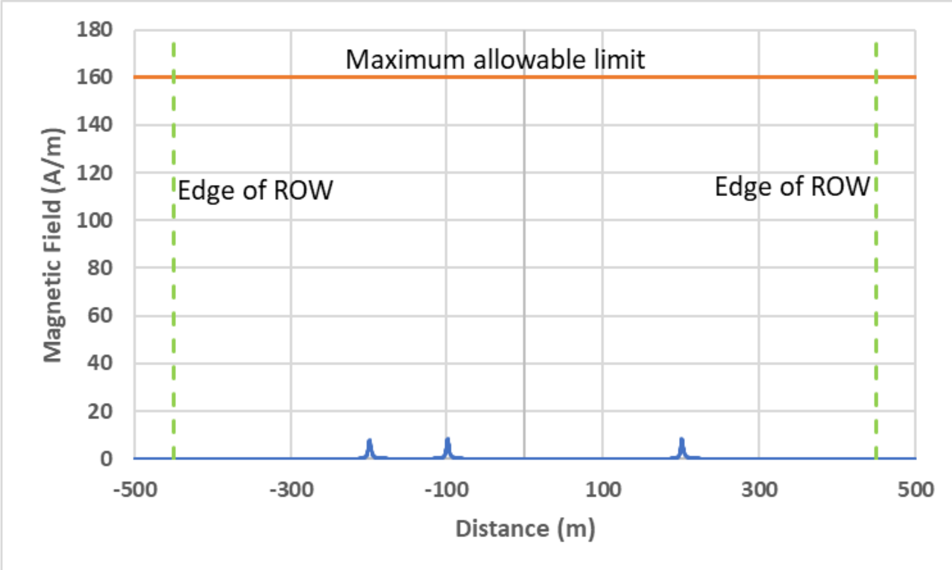

Figure 4-75 Magnetic Field Result of Case 28 with Maximum Limit

4.1.29 Case 29

Case 29 relates to HVAC Offshore export cable (2000 mm^2 Cu). Landfall HDD profile - 4 offshore export cables (230 kV) NJ Route. EMF assessment at seabed.

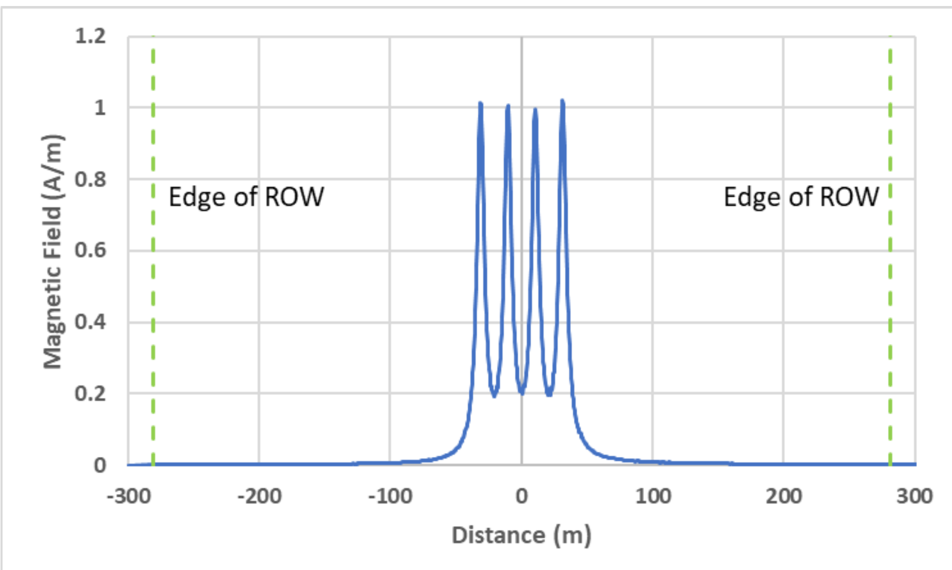

Figure 4-76 Magnetic Field Result of Case 29

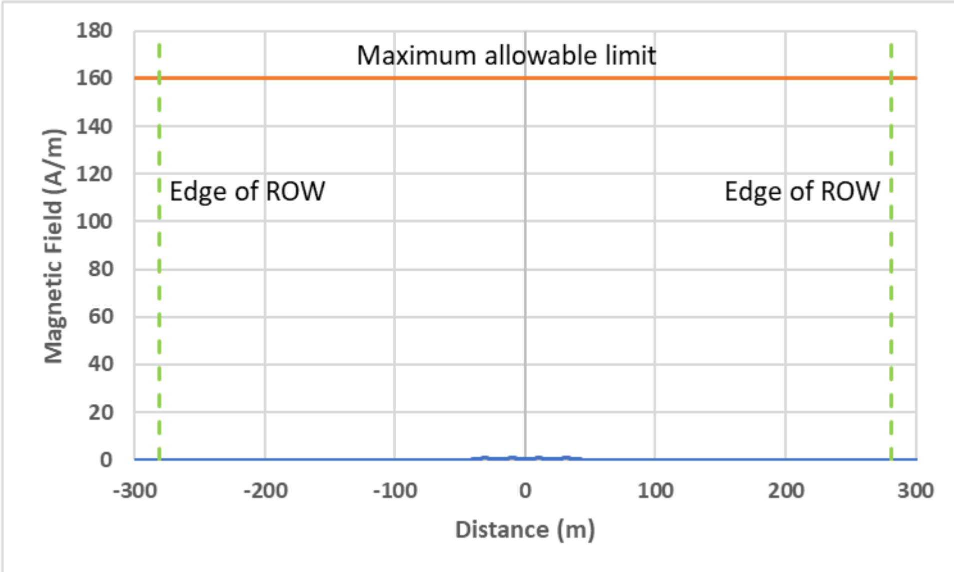

Figure 4-77 Magnetic Field Result of Case 29 with Maximum Limit

4.1.30 Case 30

Case 30 relates to HVAC Offshore export cable (2000 mm^2 Cu). Buried in seabed (6' from Seabed) - 4 offshore export cables (230 kV) NJ Route. EMF assessment at seabed.

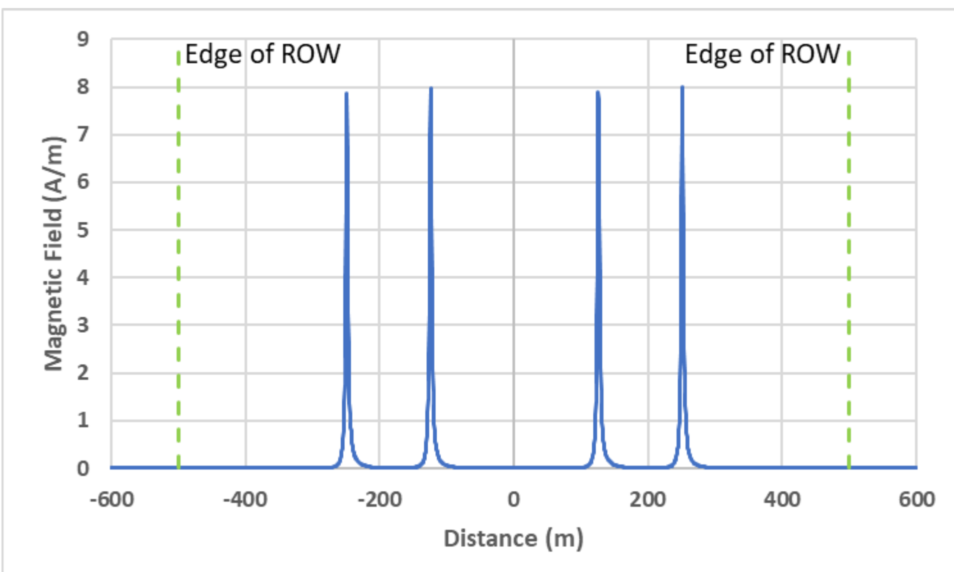

Figure 4-78 Magnetic Field Result of Case 30

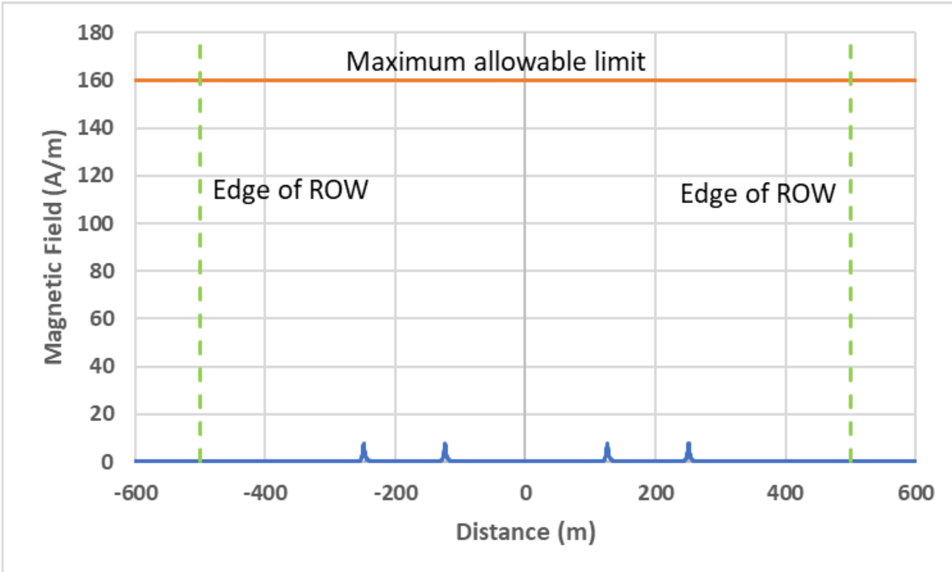

Figure 4-79 Magnetic Field Result of Case 30 with Maximum Limit

4.1.31 Case 31

Case 31 relates to HVAC Offshore export cable (2000 mm^2 Cu). Landfall HDD profile - 4 offshore export cables (275 kV) NJ Route. EMF assessment at seabed.

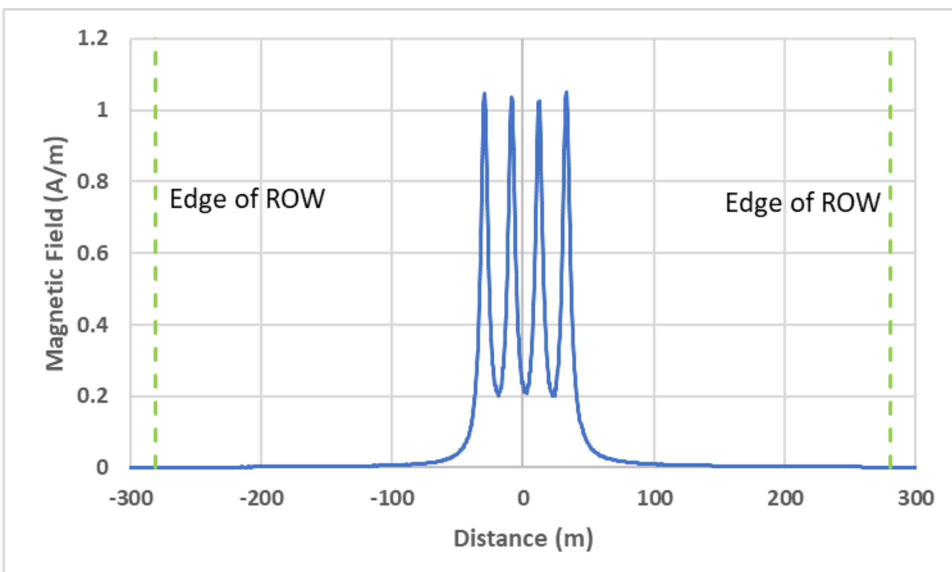

Figure 4-80 Magnetic Field Result of Case 31

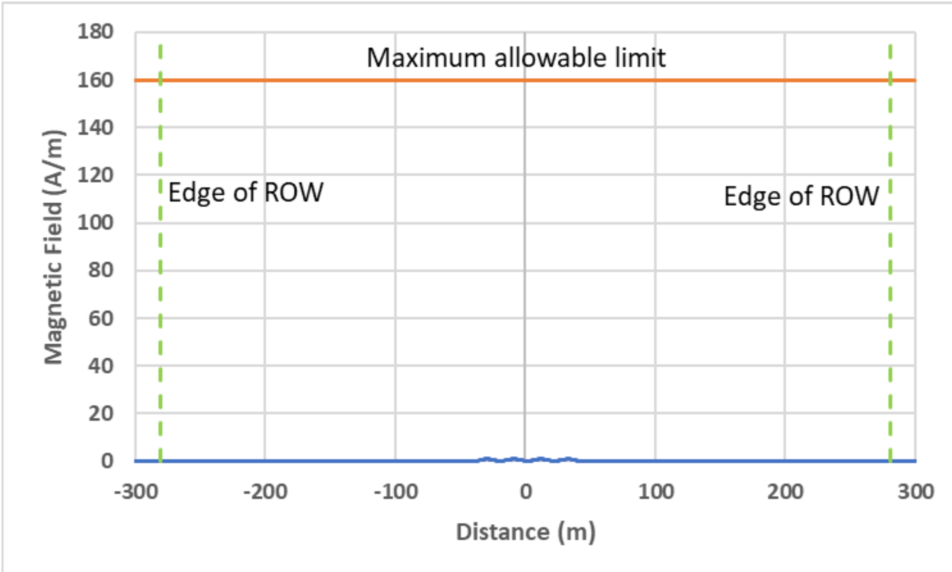

Figure 4-81 Magnetic Field Result of Case 31 with Maximum Limit

4.1.32 Case 32

Case 32 relates to HVAC Offshore export cable (2000 mm^2 Cu). Buried in seabed (6' from Seabed) - 4 offshore export cables (275 kV) NJ Route. EMF assessment at seabed.

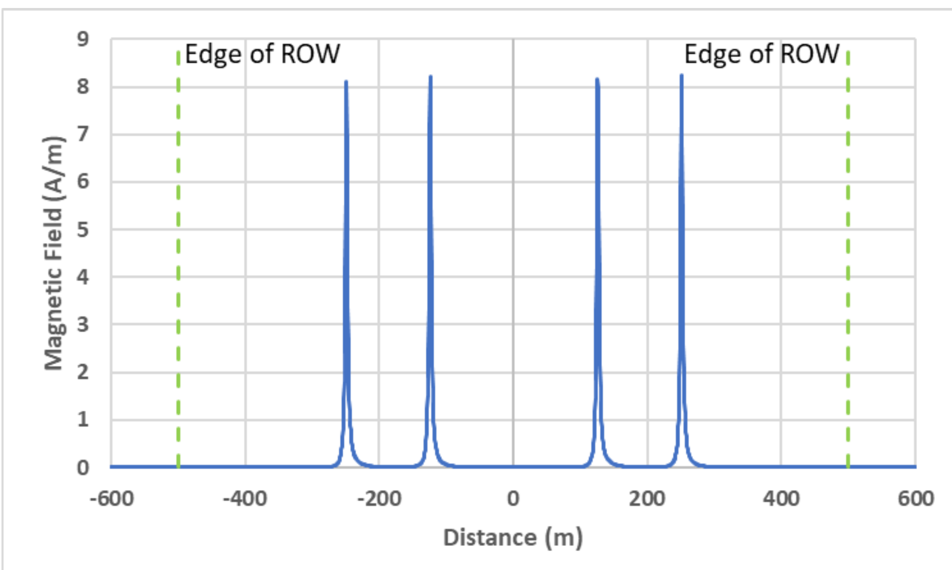

Figure 4-82 Magnetic Field Result of Case 32

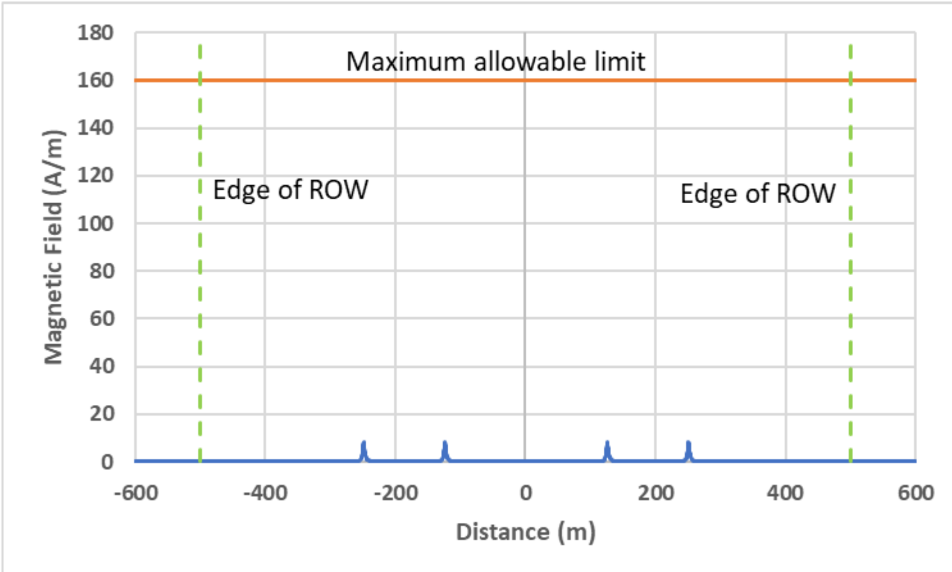

Figure 4-83 Magnetic Field Result of Case 32 with Maximum Limit

4.1.33 Case 33

Case 33 relates to HVAC Offshore export cable (2000 mm^2 Cu). Cable crossing arrangement (refer to 09_29 A131951-0309-SX-LX-0 Cab Crossing layout [47]). Buried in seabed {4 feet (1.2 m) from seabed} - 3 offshore export cables (230 kV) NY Route. EMF assessment at seabed.

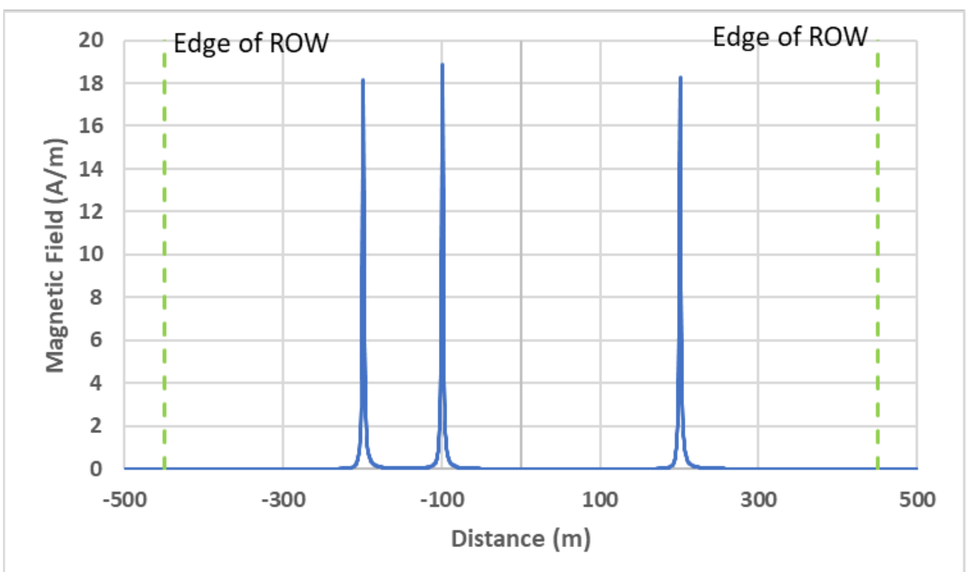

Figure 4-84 Magnetic Field Result of Case 33

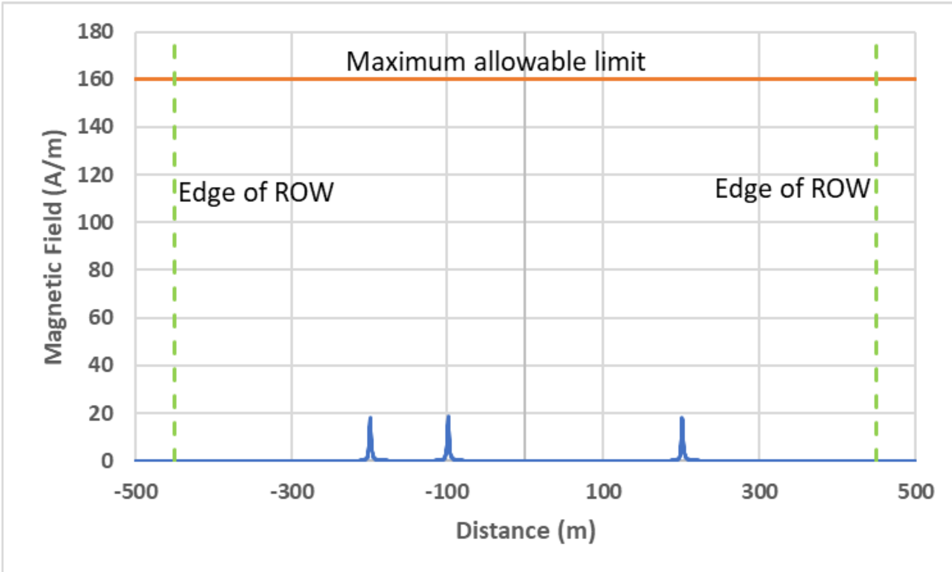

Figure 4-85 Magnetic Field Result of Case 33 with Maximum Limit

4.1.34 Case 34

Case 34 relates to HVAC Offshore export cable (2000 mm^2 Cu). Cable crossing arrangement (refer to 09_29 A131951-0309-SX-LX-0 Cab Crossing layout [47]). Buried in seabed {4 feet (1.2 m) from seabed} - 3 offshore export cables (275 kV) NY Route. EMF assessment at seabed.

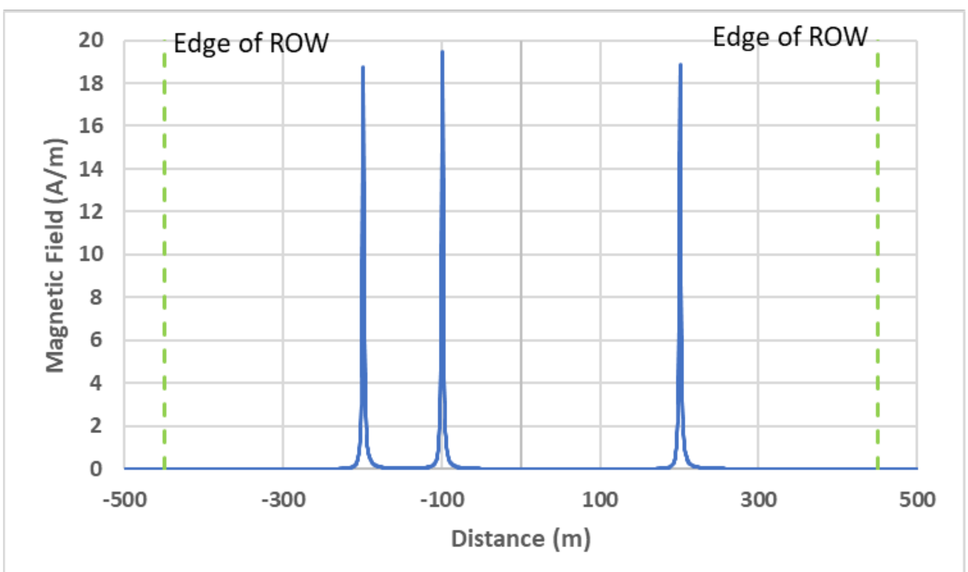

Figure 4-86 Magnetic Field Result of Case 34

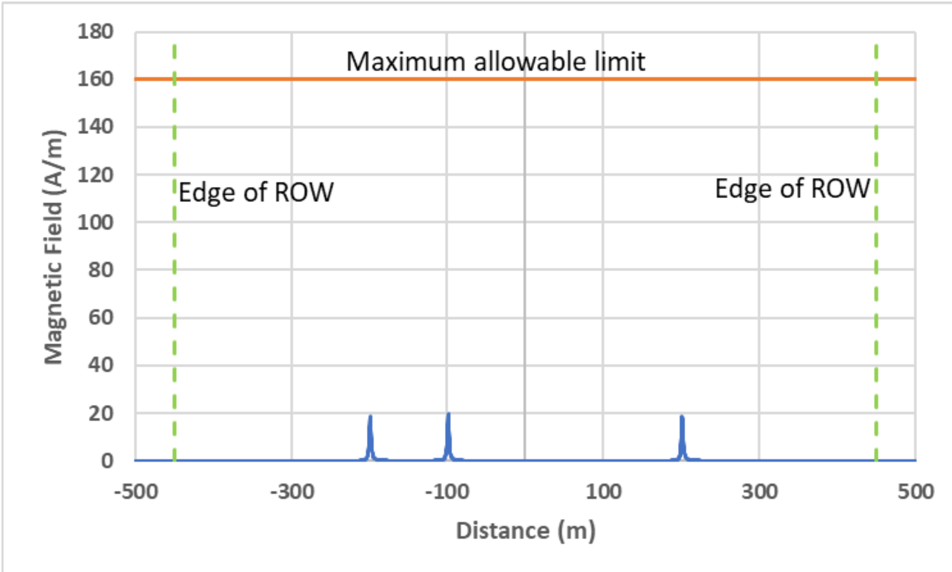

Figure 4-87 Magnetic Field Result of Case 34 with Maximum Limit

4.1.35 Case 35

Case 35 relates to HVAC Offshore export cable (2000 mm^2 Cu). Cable crossing arrangement (refer to 09_29 A131951-0309-SX-LX-0 Cab Crossing layout [47]). Buried in seabed {4 feet (1.2 m) from seabed} - 4 offshore export cables (230 kV) NJ Route. EMF assessment at seabed.

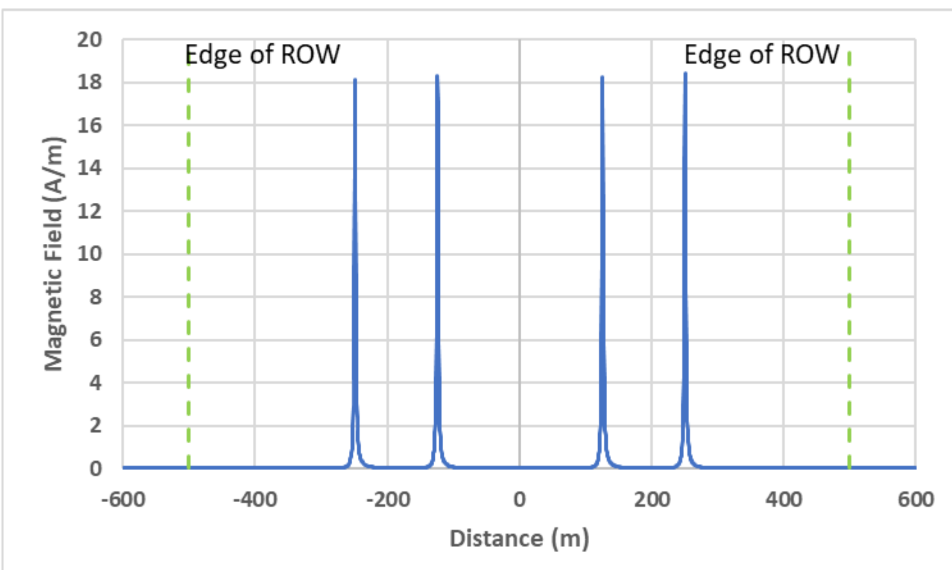

Figure 4-88 Magnetic Field Result of Case 35

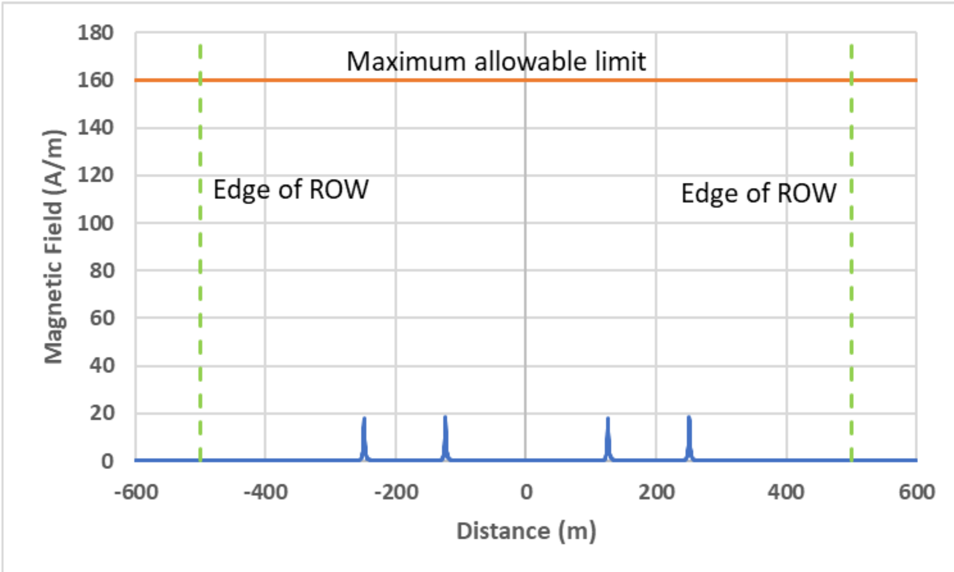

Figure 4-89 Magnetic Field Result of Case 35 with Maximum Limit

4.1.36 Case 36

Case 36 relates to HVAC Offshore export cable (2000 mm² Cu). Cable crossing arrangement (refer to 09_29 A131951-0309-SX-LX-0 Cab Crossing layout [47]). Buried in seabed (4 feet (1.2 m) from seabed) - 4 offshore export cables (275 kV) NJ Route. EMF assessment at seabed.

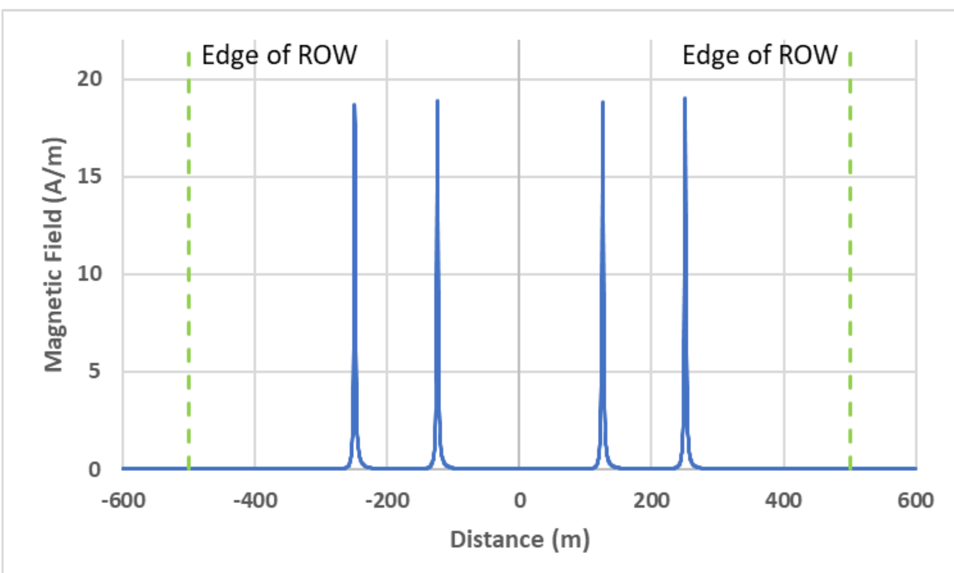

Figure 4-90 Magnetic Field Result of Case 36

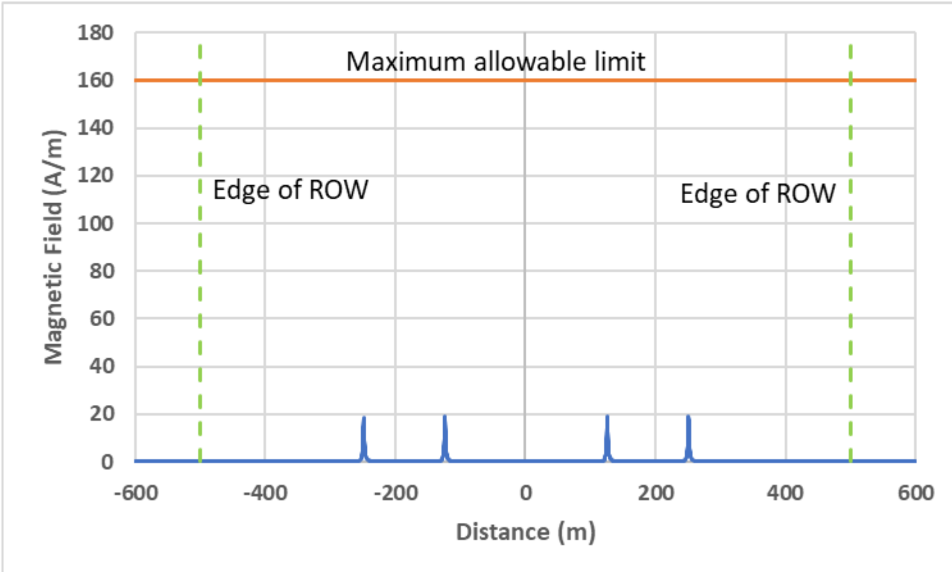

Figure 4-91 Magnetic Field Result of Case 36 with Maximum Limit

4.1.37 Case 37

Case 37 relates to 320 kV HVDC Offshore export bundled cable (2500 mm^2 Cu). Landfall HDD profile. EMF assessment at seabed.

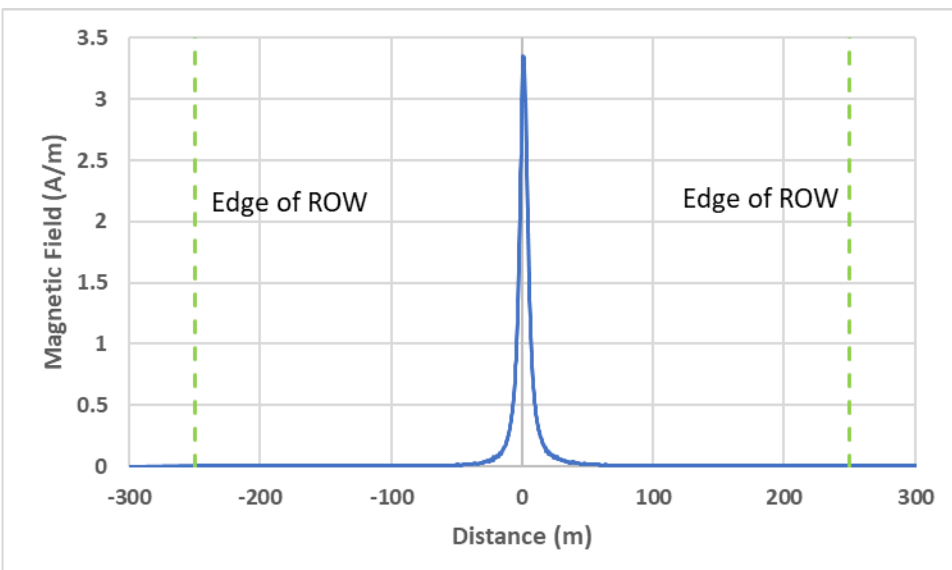

Figure 4-92 Magnetic Field Result of Case 37

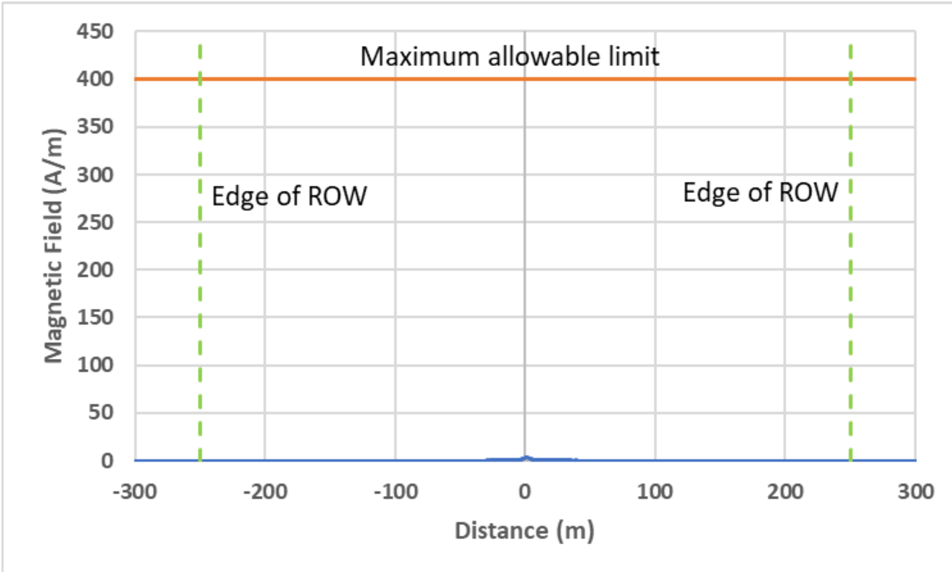

Figure 4-93 Magnetic Field Result of Case 37 with Maximum Limit

4.1.38 Case 38

Case 38 relates to 320 kV HVDC Offshore export bundled cable (2500 mm^2 Cu). Buried in seabed (6’ from seabed). EMF assessment at seabed.

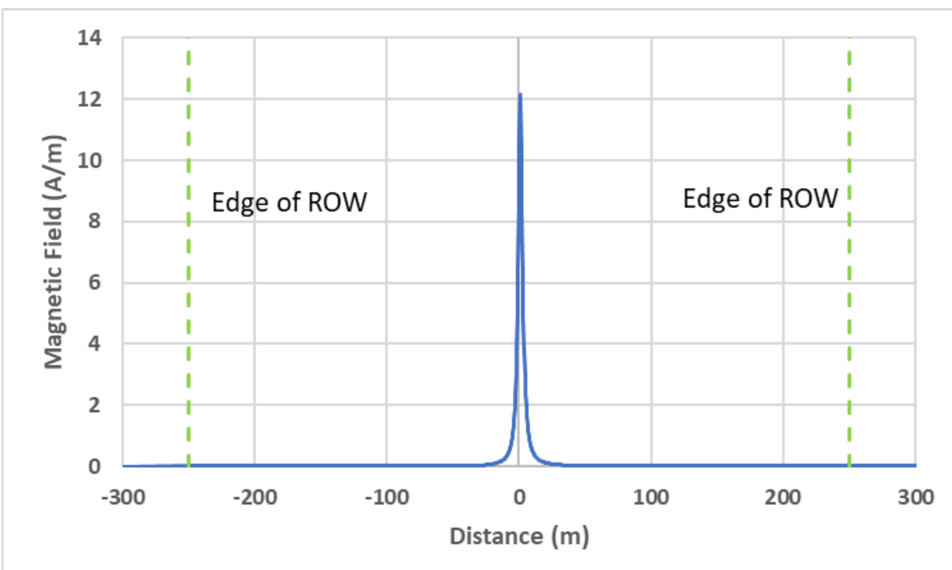

Figure 4-94 Magnetic Field Result of Case 38

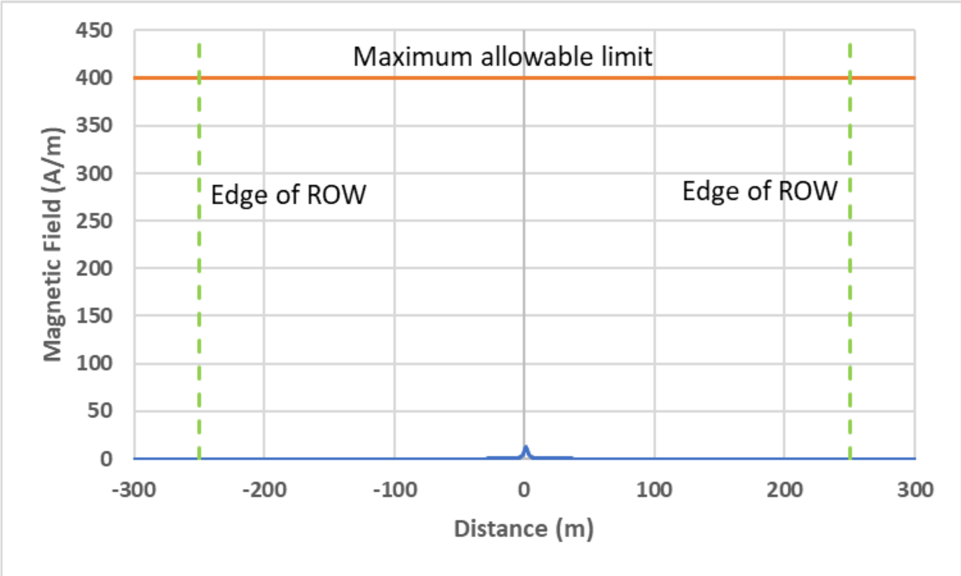

Figure 4-95 Magnetic Field Result of Case 38 with Maximum Limit

4.1.39 Case 39

Case 39 relates to 320 kV HVDC Offshore export bundled cable (2500 mm^2 Cu). Cable Crossing arrangement (refer to 09_29 A131951-0309-SX-LX-0 Cab Crossing layout [47]). Buried in seabed {4 feet (1.2 m) from seabed}. EMF assessment at seabed.

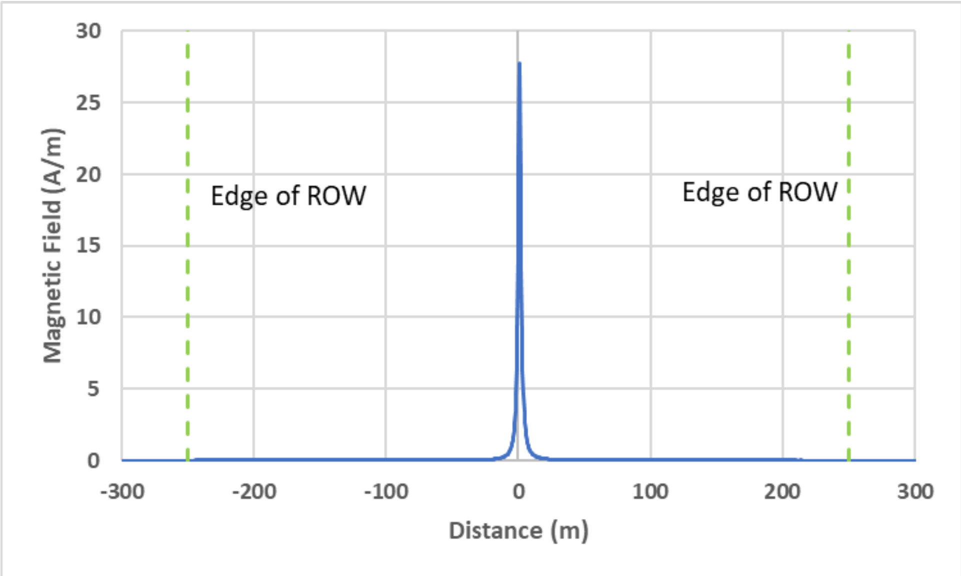

Figure 4-96 Magnetic Field Result of Case 39

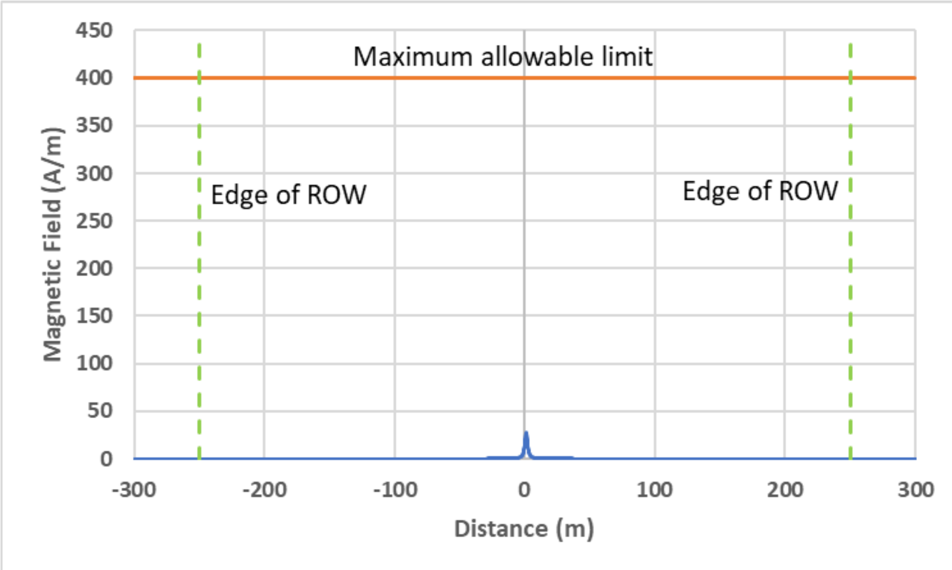

Figure 4-97 Magnetic Field Result of Case 39 with Maximum Limit

4.1.40 Case 40

Case 40 relates to 525 kV Offshore HVDC offshore export cable laid with 328.084 feet separation distance between positive and negative poles (2500 mm^2 Cu). Landfall HDD profile. EMF assessment at seabed.

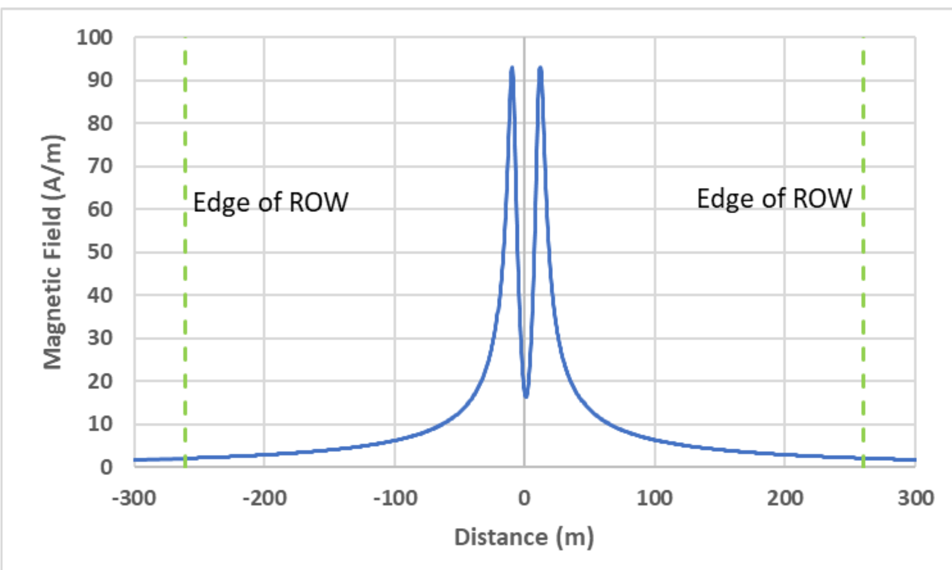

Figure 4-98 Magnetic Field Result of Case 40

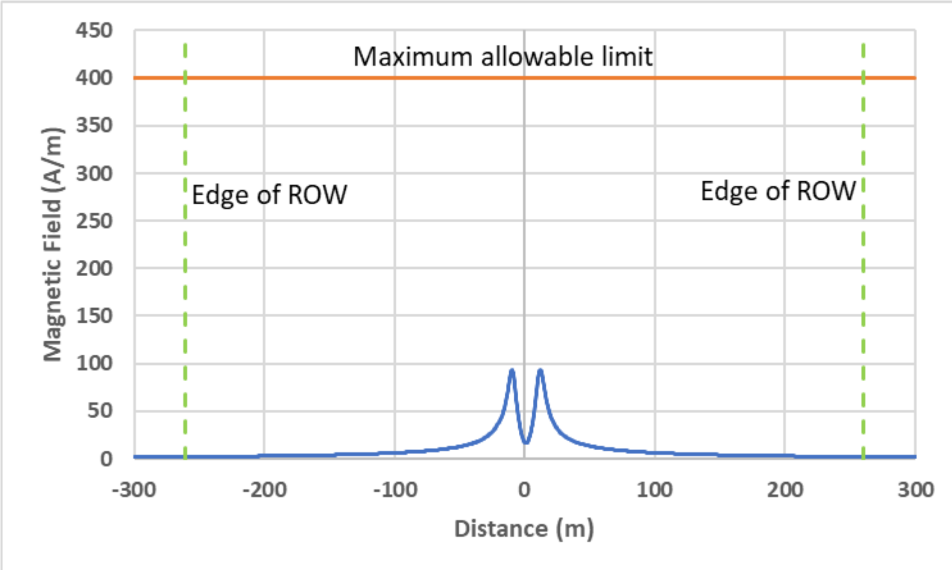

Figure 4-99 Magnetic Field Result of Case 40 with Maximum Limit

4.1.41 Case 41

Case 41 relates to 525 kV HVDC Offshore export cable laid with 328.084 feet separation distance between positive and negative poles (2500 mm^2 Cu). Buried in seabed (6’ from Seabed). EMF assessment at seabed.

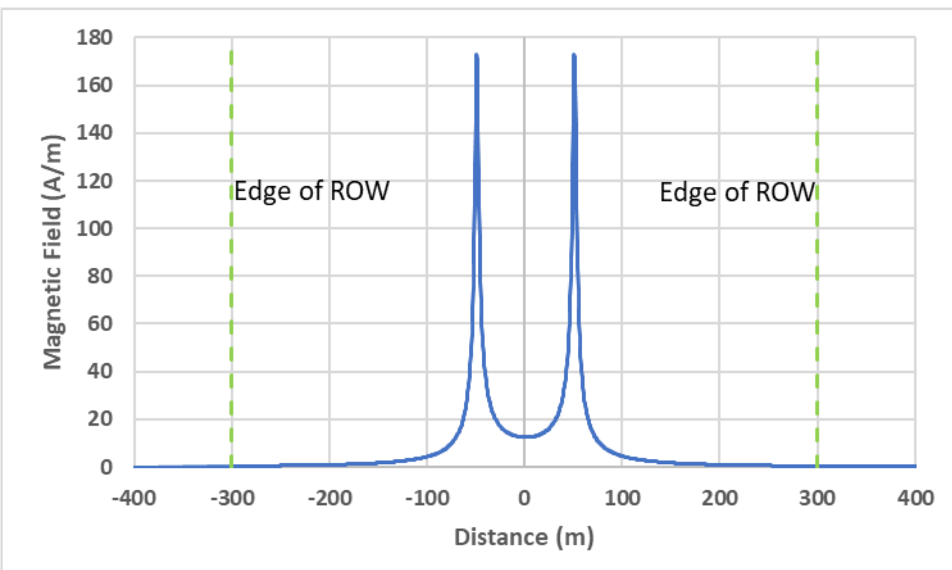

Figure 4-100 Magnetic Field Result of Case 41

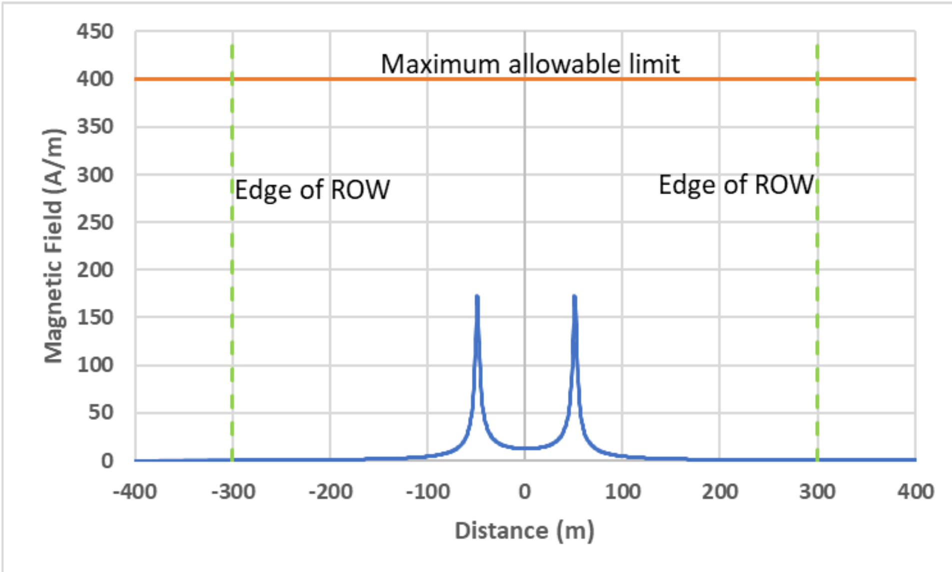

Figure 4-101 Magnetic Field Result of Case 41 with Maximum Limit

4.1.42 Case 42

Case 42 relates to 525 kV HVDC Offshore export cable laid with 328.084 feet separation distance between positive and negative poles (2500 mm^2 Cu). Cable crossing arrangement (refer to 09_29 A131951-0309-SX-LX-0 Cab Crossing layout [47]). Buried in seabed {4 feet (1.2 m) from seabed}. EMF assessment at seabed.

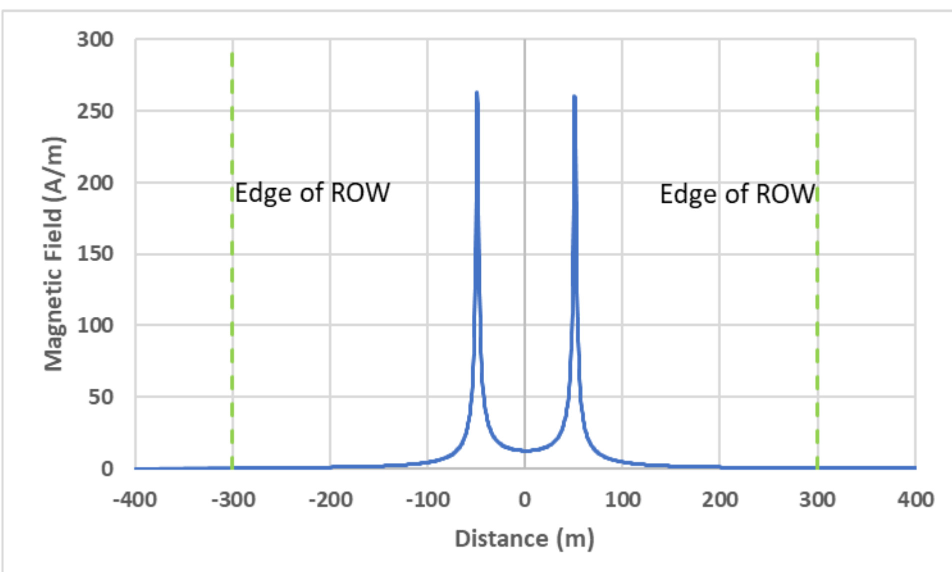

Figure 4-102 Magnetic Field Result of Case 42

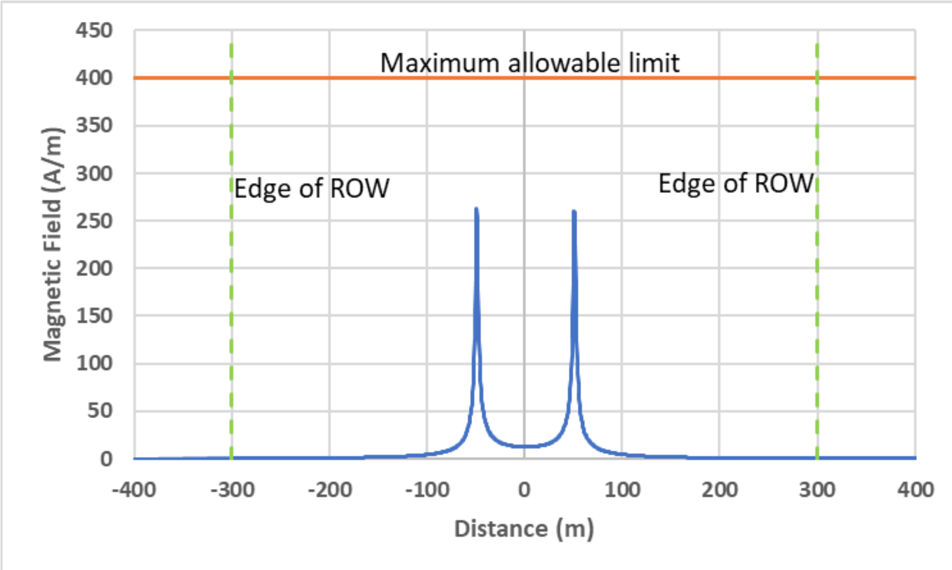

Figure 4-103 Magnetic Field Result of Case 42 with Maximum Limit

4.1.43 Case 43

Case 43 relates to 230 kV HVAC Onshore interconnection transmission cable (3000 mm^2 Cu Single Core) laid in trench in narrow corridor - 4 circuits arrangement. EMF assessment at surface.

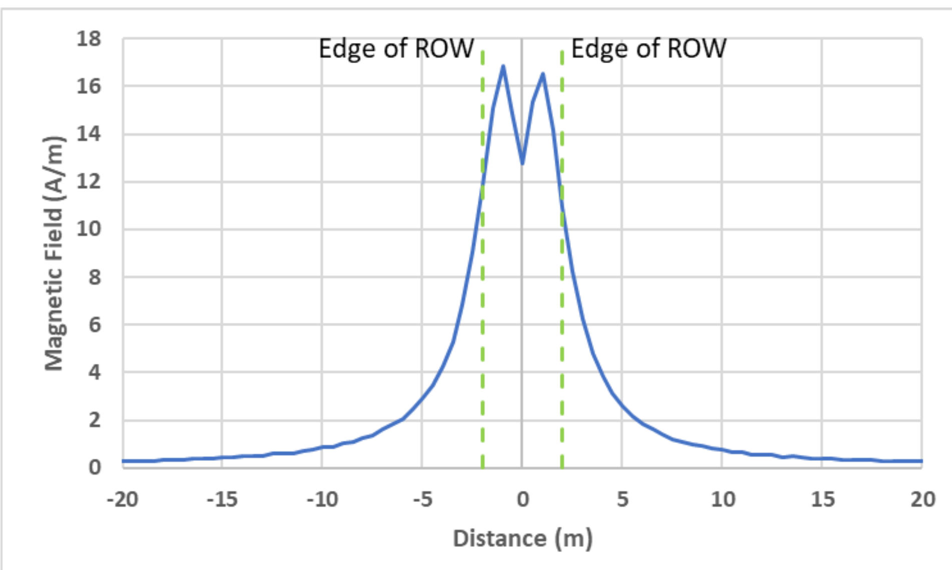

Figure 4-104 Magnetic Field Result of Case 43

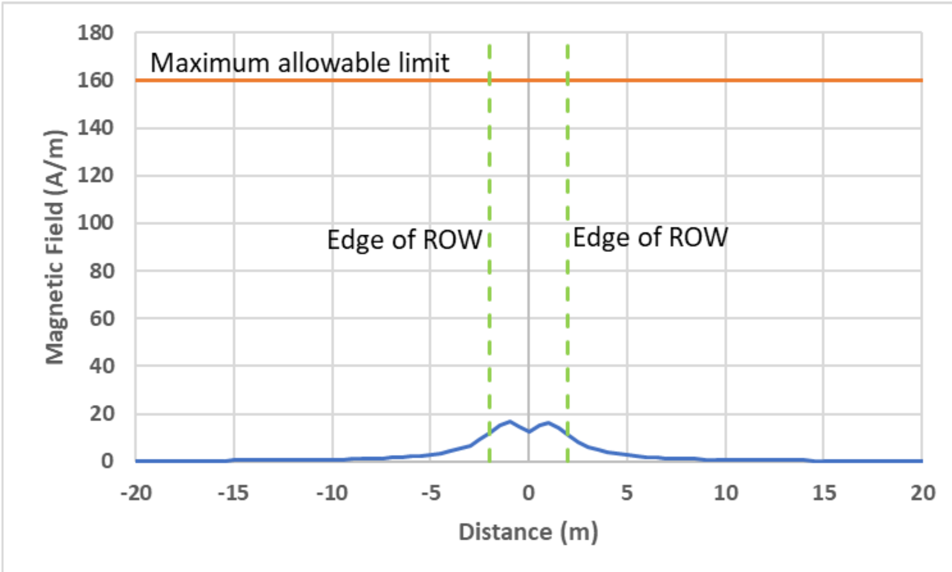

Figure 4-105 Magnetic Field Result of Case 43 with Maximum Limit

4.1.44 Case 44

Case 44 relates to 275 kV HVAC Onshore interconnection transmission cable (3000 mm^2 Cu Single Core) laid in trench in narrow corridor - 4 circuits arrangement. EMF assessment at surface.

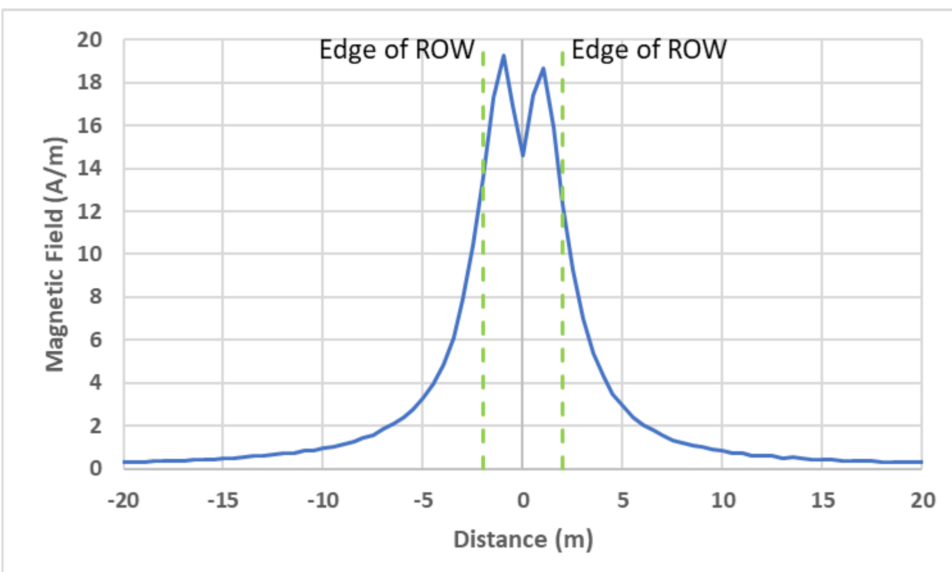

Figure 4-106 Magnetic Field Result of Case 44

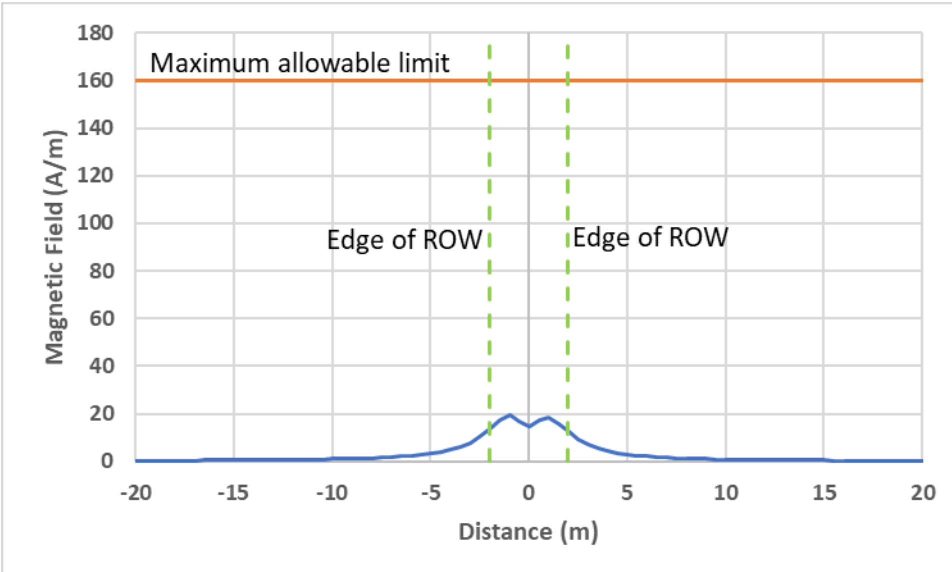

Figure 4-107 Magnetic Field Result of Case 44 with Maximum Limit

4.1.45 Case 45

Case 45 relates to 230 kV HVAC Onshore interconnection transmission cable (3000 mm^2 Cu Single Core) laid in HDD at 3.28 feet (1 m) depth and 10 feet (3 m) separation - 4 circuits. EMF assessment at surface.

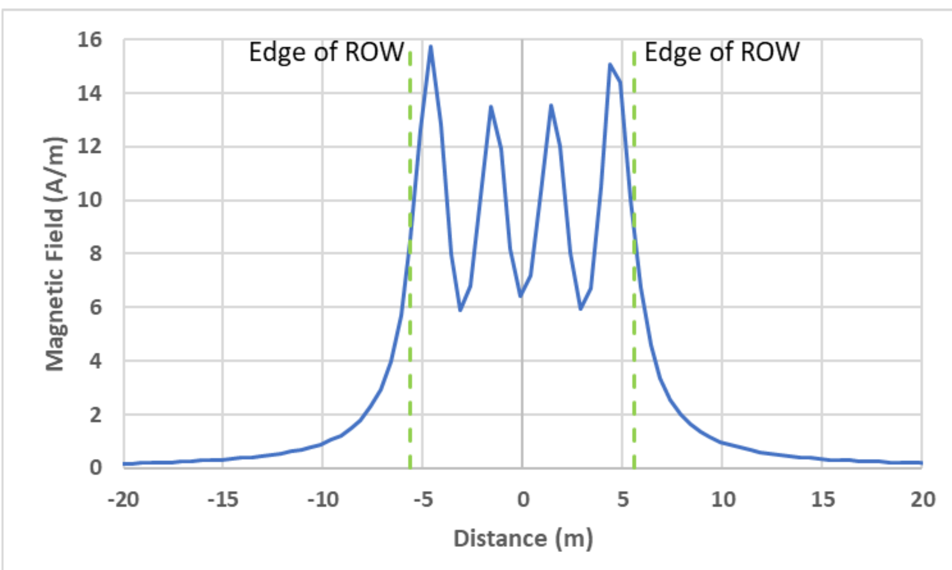

Figure 4-108 Magnetic Field Result of Case 45

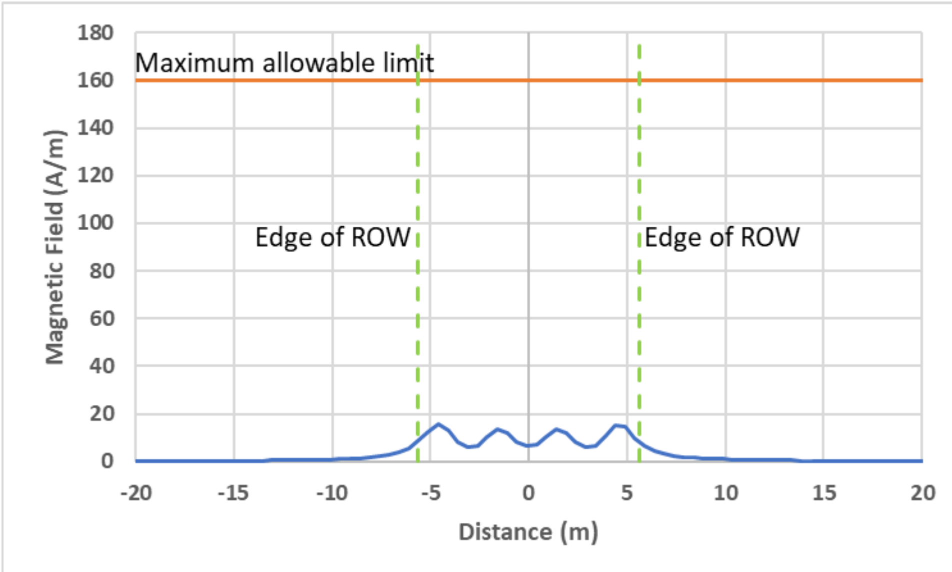

Figure 4-109 Magnetic Field Result of Case 45 with Maximum Limit

4.1.46 Case 46

Case 46 relates to 275 kV HVAC Onshore interconnection transmission cable (3000 mm^2 Cu Single Core) laid in HDD at 3.28 feet (1 m) depth and 10 feet (3 m) separation - 4 circuits. EMF assessment at surface.

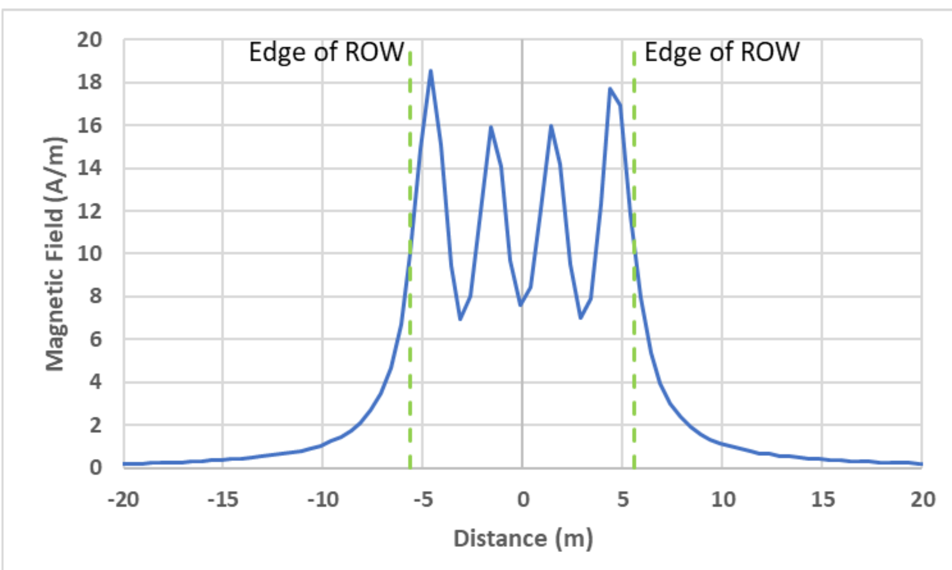

Figure 4-110 Magnetic Field Result of Case 46

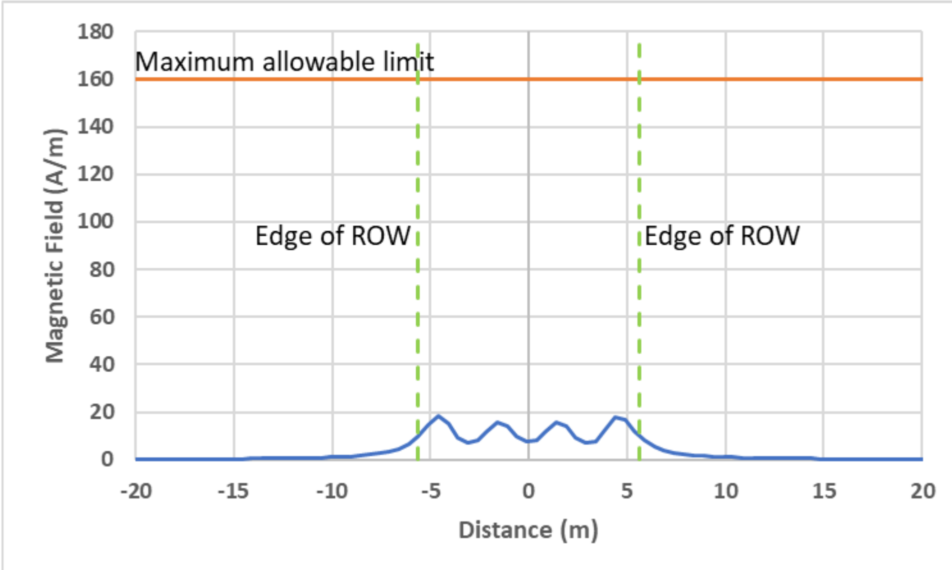

Figure 4-111 Magnetic Field Result of Case 46 with Maximum Limit

4.1.47 Case 47

Case 47 relates to 230 kV HVAC Overhead transmission line from Onshore substation to Larrabee POI. EMF assessment at 3.28 feet above ground surface.

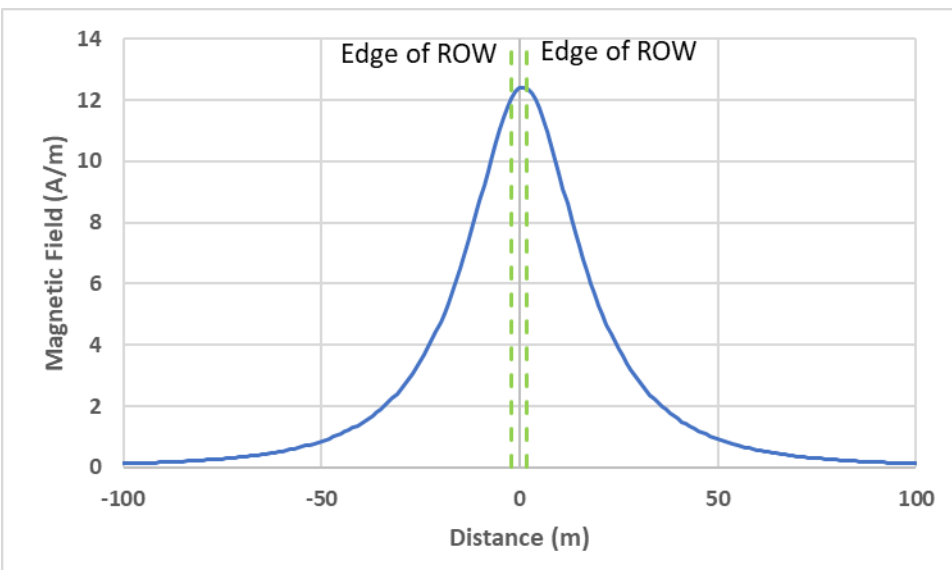

Figure 4-112 Magnetic Field Result of Case 47

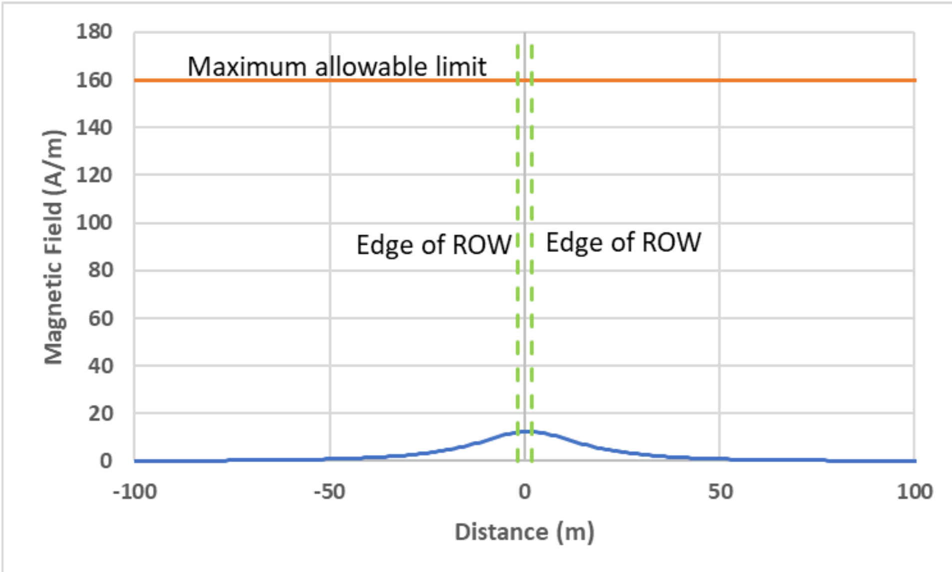

Figure 4-113 Magnetic Field Result of Case 47 with Maximum Limit

4.1.48 Case 48

Case 48 relates to 320 kV HVDC Onshore interconnection transmission cable (2500 mm^2 Cu) laid in trench. EMF assessment at surface.

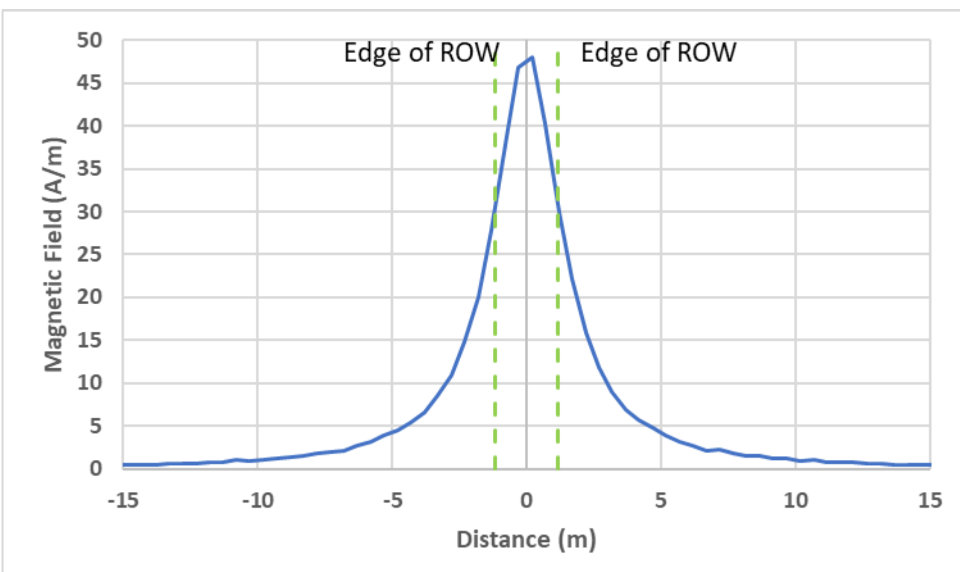

Figure 4-114 Magnetic Field Result of Case 48

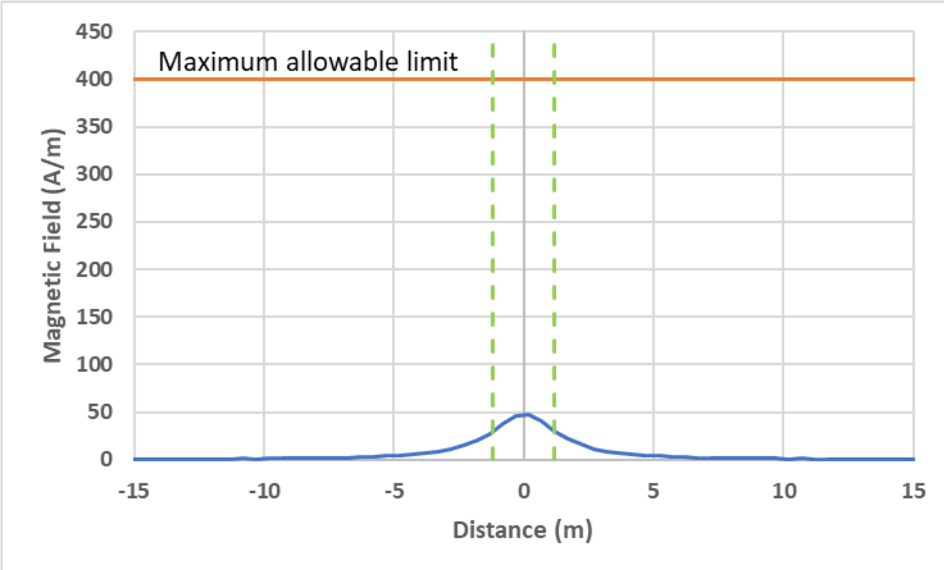

Figure 4-115 Magnetic Field Result of Case 48 with Maximum Limit

4.1.49 Case 49

Case 49 relates to 320 kV HVDC Onshore interconnection transmission cable (2500 mm^2 Cu) laid in HDD. EMF assessment at surface.

Four separate cases were studied for Case 49 to consider various spacing between the positive and negative cables as well as depths from ground surface as follows:

Figures 4-116 & 117 – Positive and Negative Poles within same duct and buried at 23 feet (7 m) from ground.
Figures 4-118 & 119 – Positive and Negative Poles in separate ducts spaced 10 feet (3 m) apart and buried 23 feet (7 m) from ground.
Figures 4-120 & 121 – Positive and Negative Poles within same duct and buried at 10 feet (3 m) from ground.
Figures 4-122& 123 – Positive and Negative Poles in separate ducts spaced 10 feet (3 m) apart and buried 10 feet (3 m) from ground.

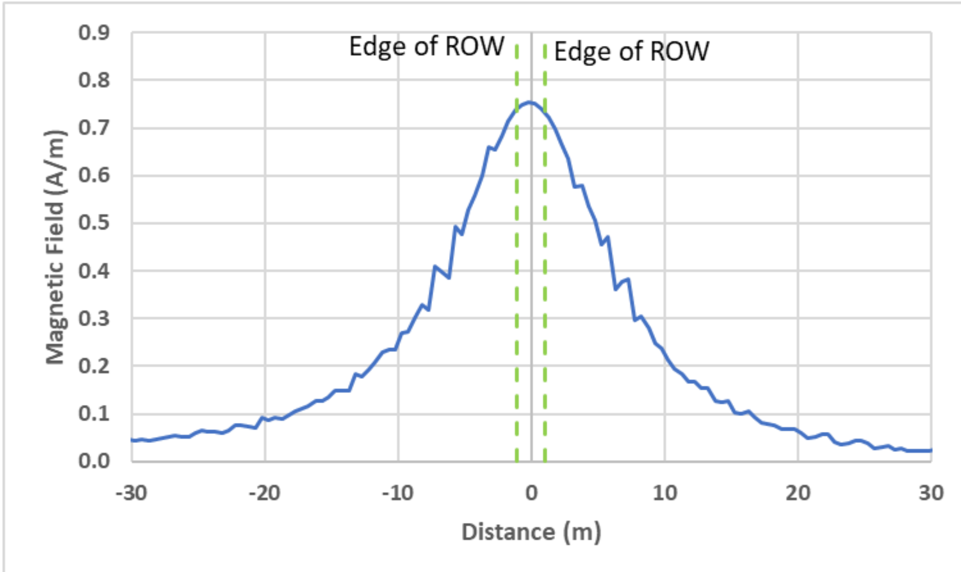

Figure 4-116 Magnetic Field Result of Case 49

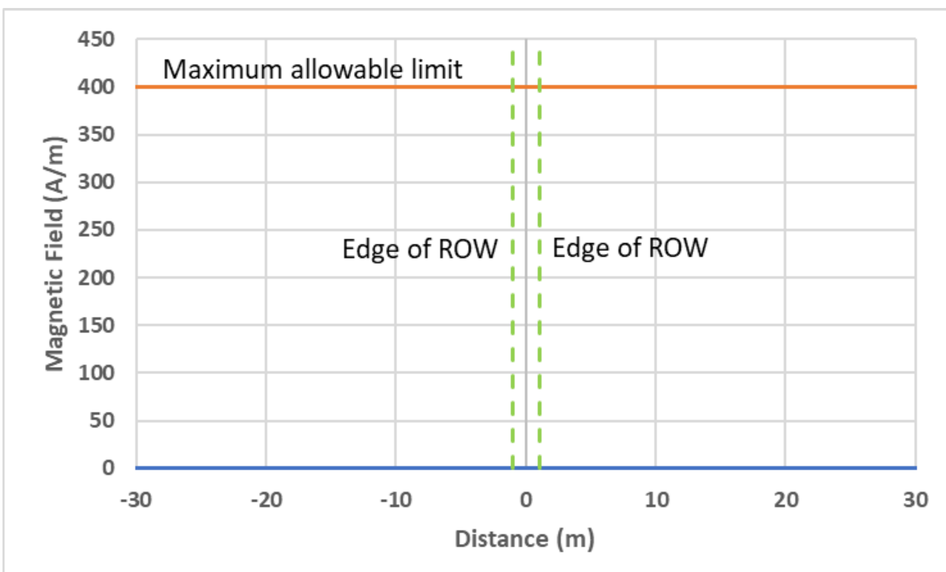

Figure 4-117 Magnetic Field Result of Case 49 with Maximum Limit

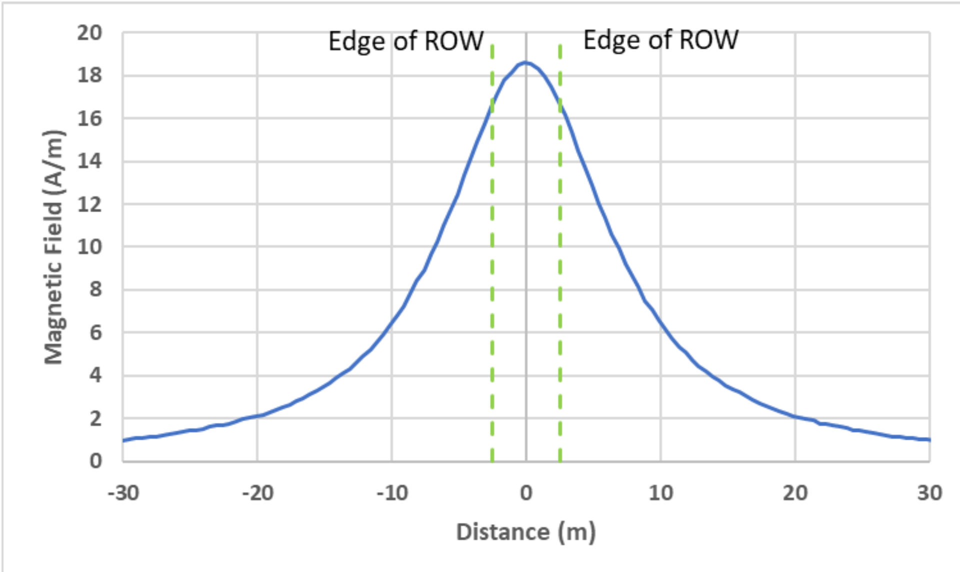

Figure 4-118 Magnetic Field Result of Case 49-1

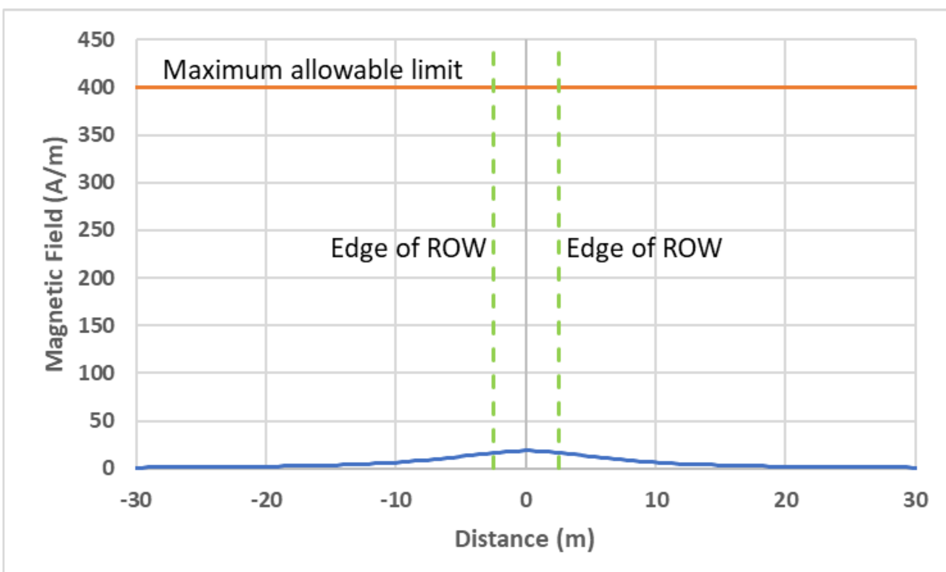

Figure 4-119 Magnetic Field Result of Case 49-1 with Maximum Limit

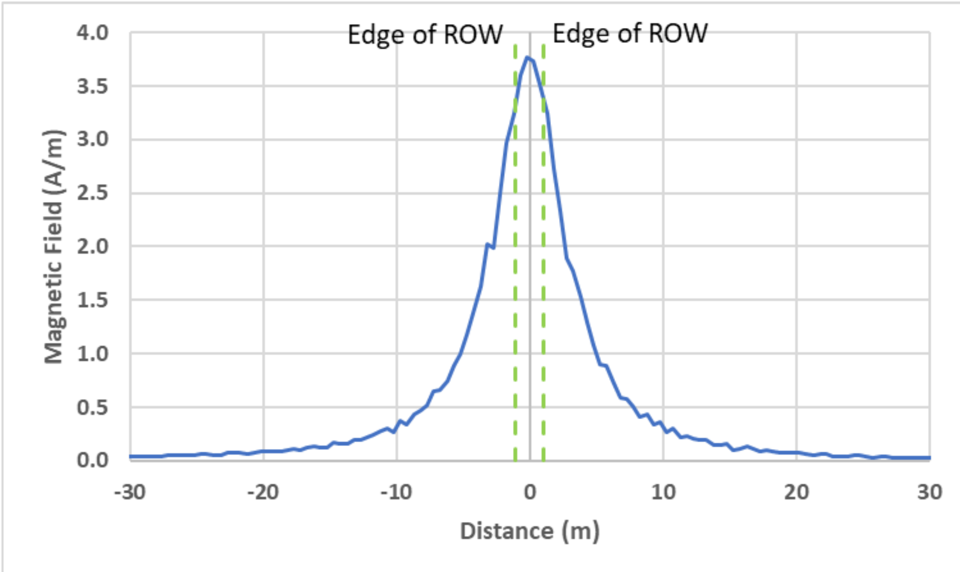

Figure 4-120 Magnetic Field Result of Case 49-2

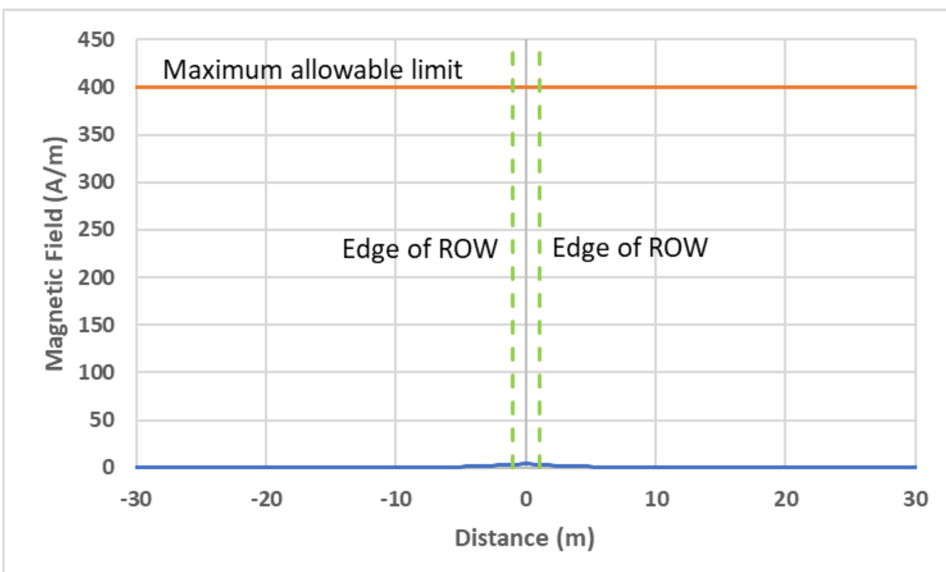

Figure 4-121 Magnetic Field Result of Case 49-2 with Maximum Limit

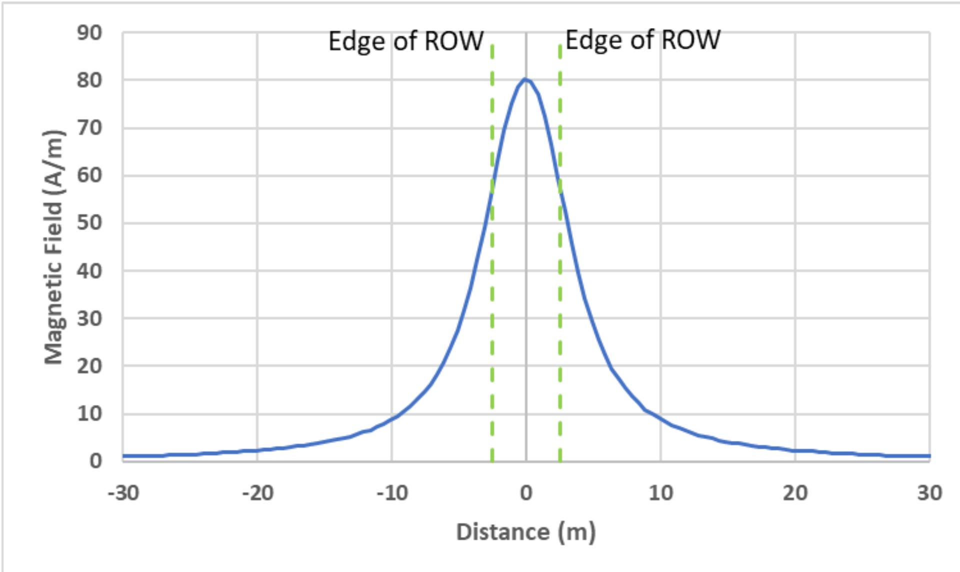

Figure 4-122 Magnetic Field Result of Case 49-3

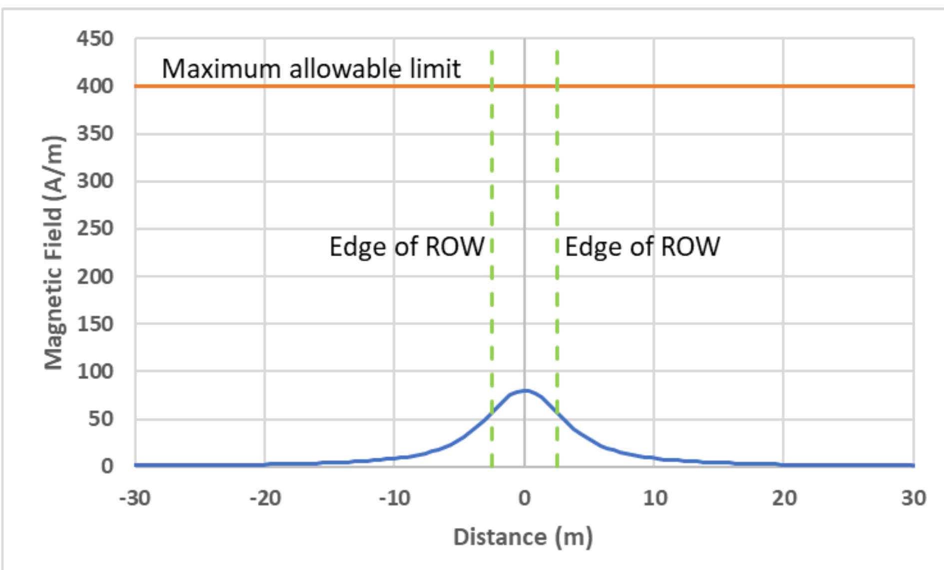

Figure 4-123 Magnetic Field Result of Case 49-3 with Maximum Limit

4.1.50 Case 50

Case 50 relates to 525 kV HVDC Onshore interconnection transmission cable (2500 mm^2 Cu) laid in trench and operating in bipole mode. EMF assessment at surface.

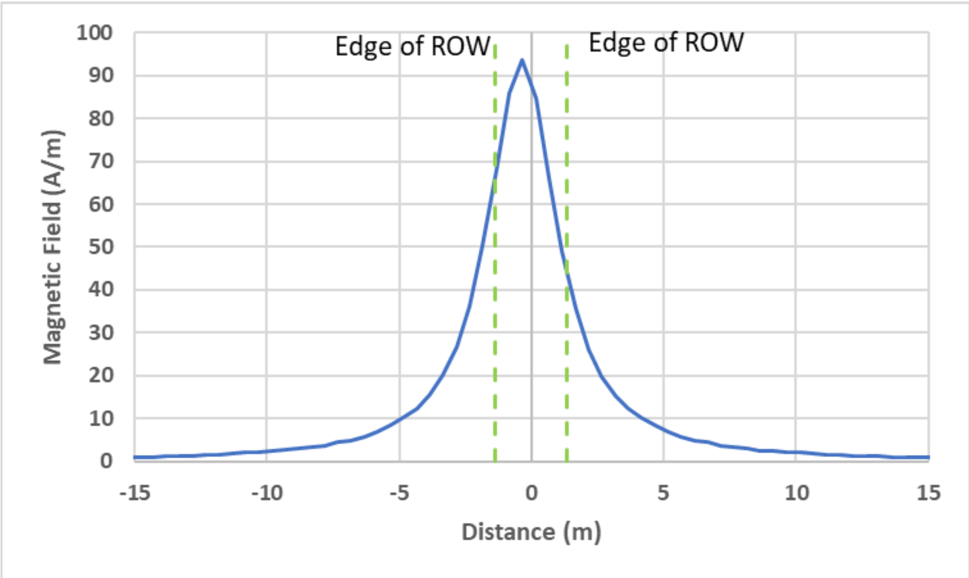

Figure 4-124 Magnetic Field Result of Case 50

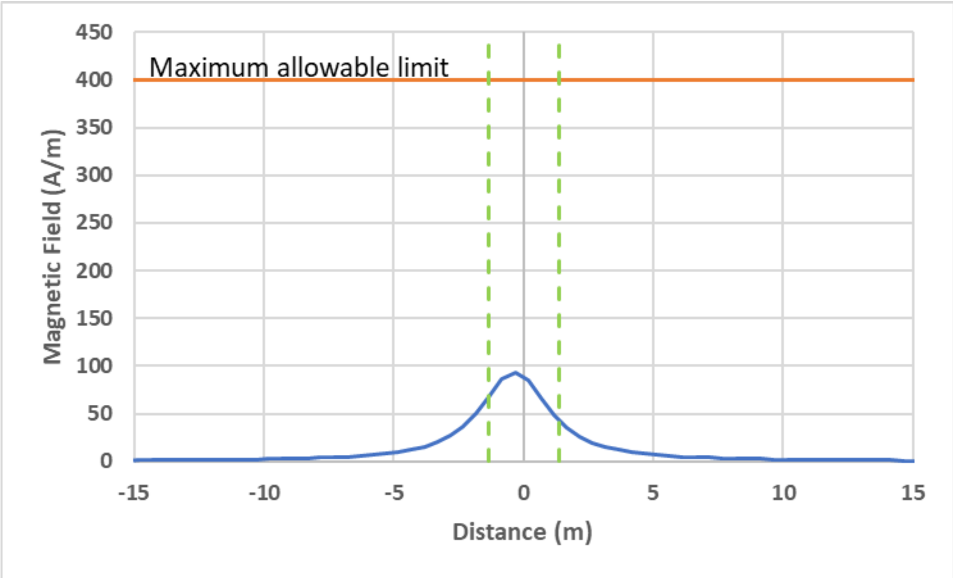

Figure 4-125 Magnetic Field Result of Case 50 with Maximum Limit

4.1.51 Case 51

Case 51 relates to 525 kV HVDC Onshore interconnection transmission cable (2500 mm^2 Cu) laid in HDD. EMF assessment at surface.

Three separate cases were studied for Case 51 to consider various spacing between the positive and negative cables as follows. The depths of all ducts are set to 10 feet (3 m) from ground.

Figures 4-126 & 127 – Positive and Negative Poles within same duct
Figures 4-128 & 129 – Positive and Negative Poles in separate ducts spaced 6.56 feet (2 m) apart
Figures 4-130 & 131 – Positive and Negative Poles in separate ducts spaced 3.28 feet (1 m) apart

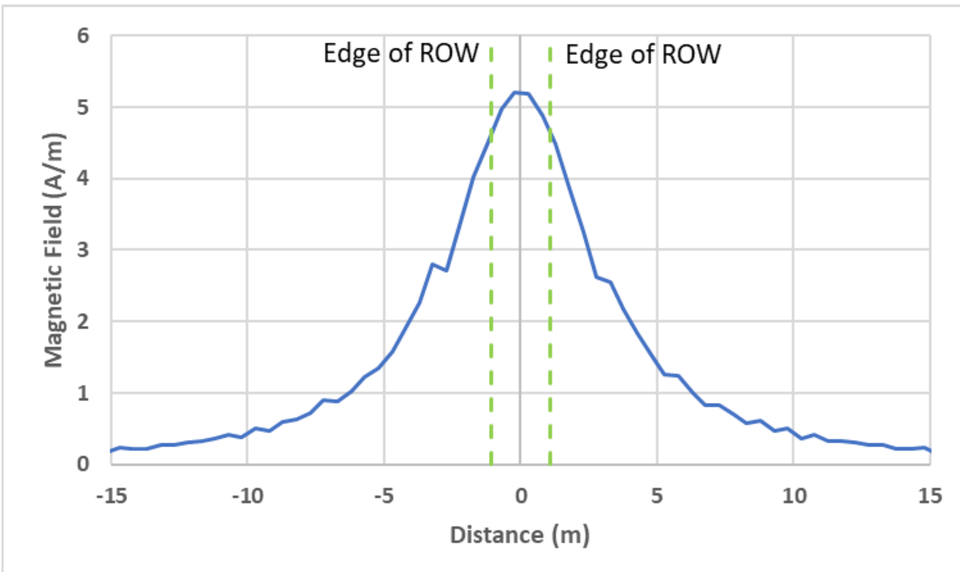

Figure 4-126 Magnetic Field Result of Case 51

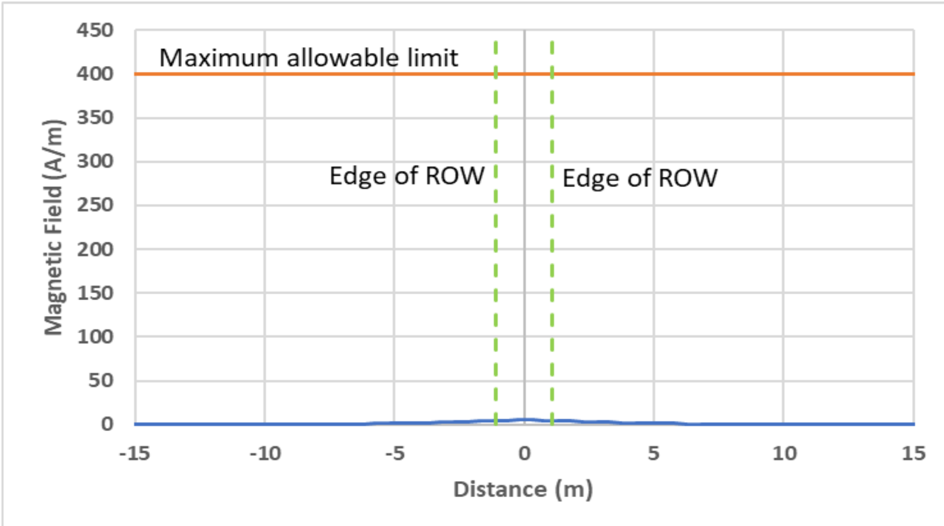

Figure 4-127 Magnetic Field Result of Case 51 with Maximum Limit

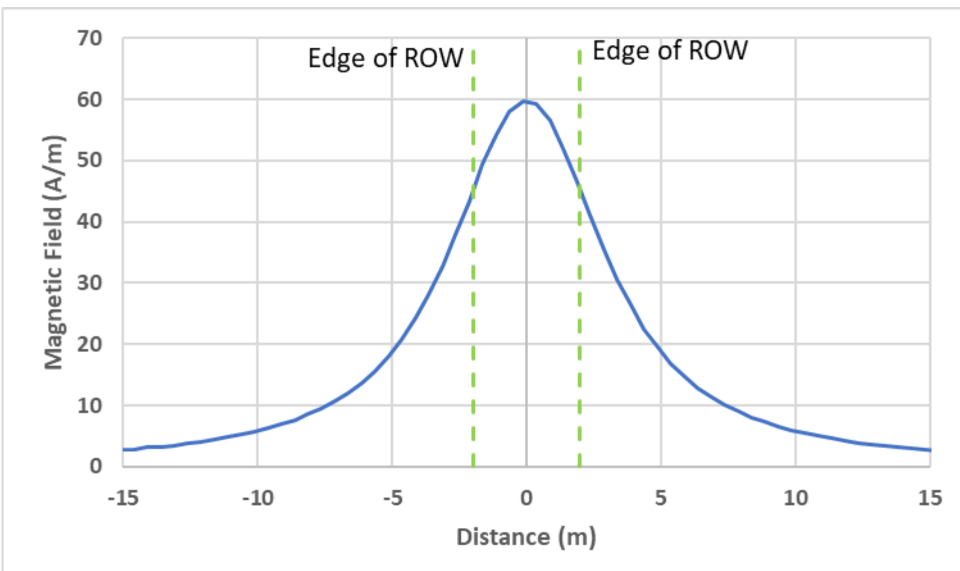

Figure 4-128 Magnetic Field Result of Case 51-1

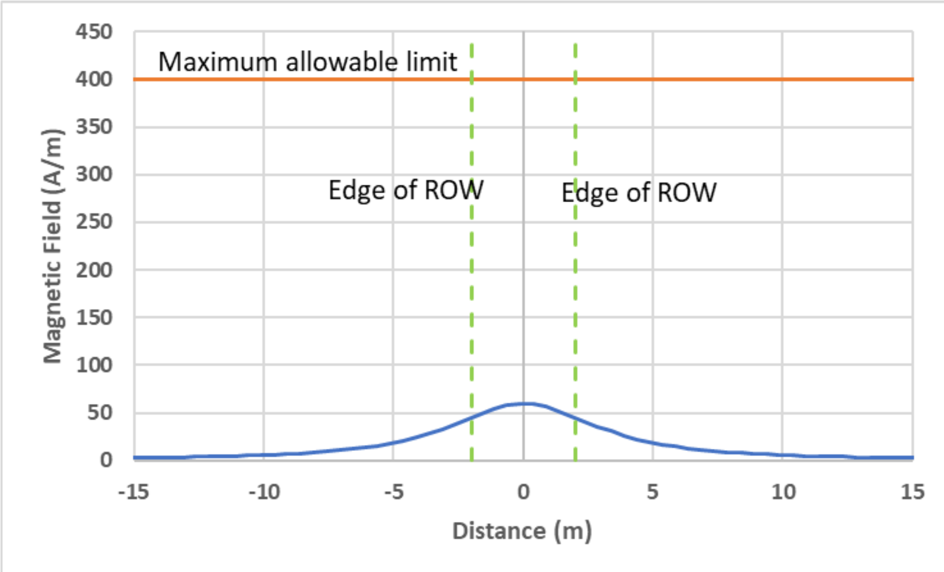

Figure 4-129 Magnetic Field Result of Case 51-1 with Maximum Limit

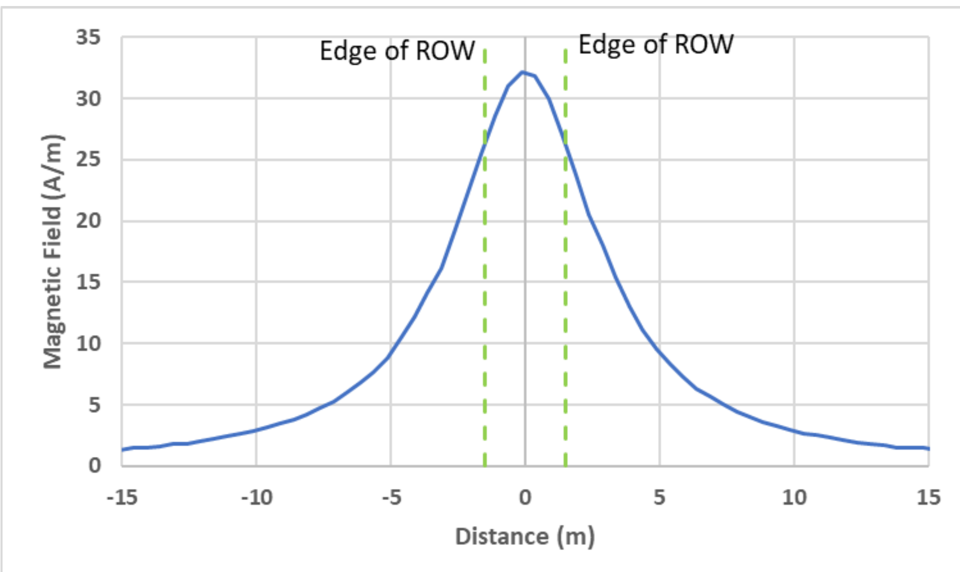

Figure 4-130 Magnetic Field Result of Case 51-2

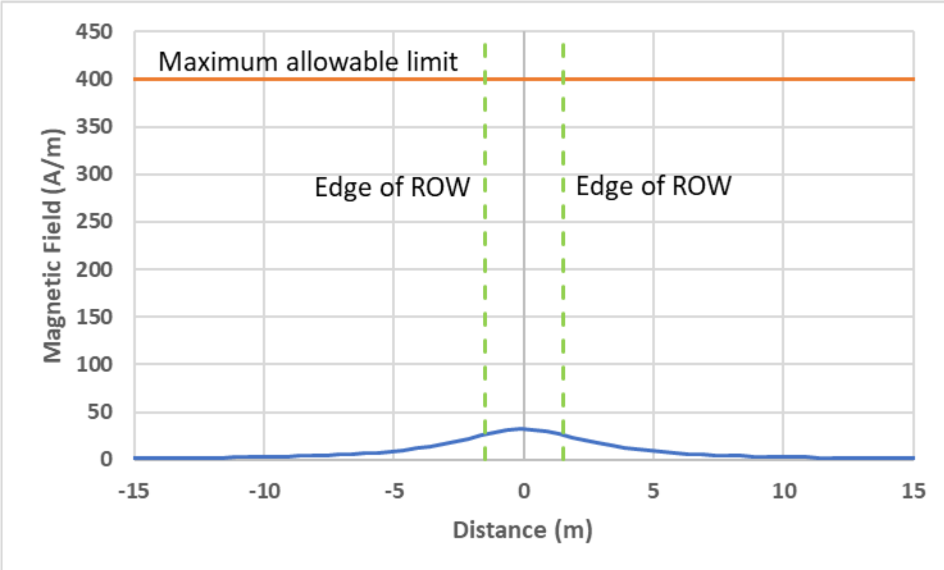

Figure 4-131 Magnetic Field Result of Case 51-2 with Maximum Limit

4.1.52 Case 52

Case 52 relates to 525 kV HVDC Onshore interconnection transmission cable (2500 mm^2 Cu) laid in trench and operating in monopole mode. EMF assessment at surface.

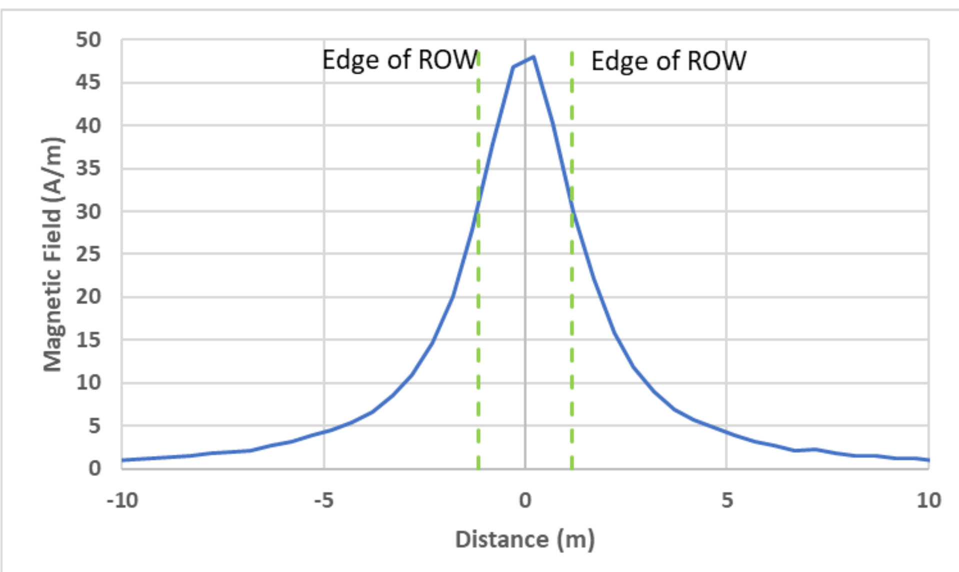

Figure 4-132 Magnetic Field Result of Case 52

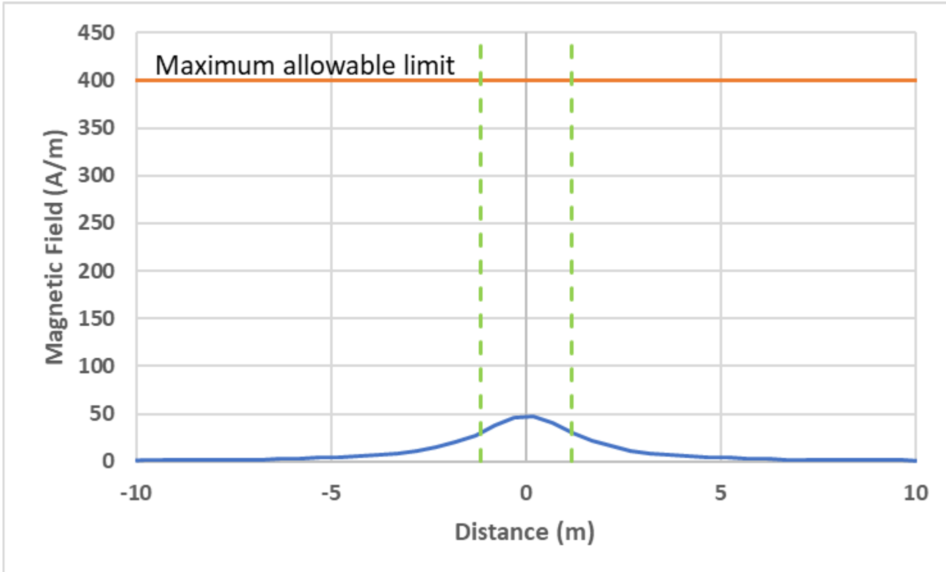

Figure 4-133 Magnetic Field Result of Case 52 with Maximum Limit

4.2 Magnetic Field Results for Substation Cases

4.2.1 Offshore Substation

This section presents the results for OSS simulated cases. Two main configurations for OSS were considered; i) HVAC configuration which includes AC inter-array cables, AC export cables and AC Gas-insulated Switchgear on collection system and export sides ii) HVDC configuration which includes AC inter-array cables, AC Gas-insulated Switchgear on collection system side and DC export cables.

4.2.1.1 HVAC Offshore Substations

As shown in Figures 4-134 and 4-135, the OSS receives the generated power by WTGs through 66 kV[4] inter-array cables. Those 66 kV inter-array cables are aggregated by a 66 kV Gas-insulated Switchgear. Then, the voltage is converted by transformers to 230 kV or 275 kV.

[4] For illustration purposes only 66 kV inter-array cable voltage level is mentioned here. IAC voltage level can either be 66, 132 or 150 kV AC.

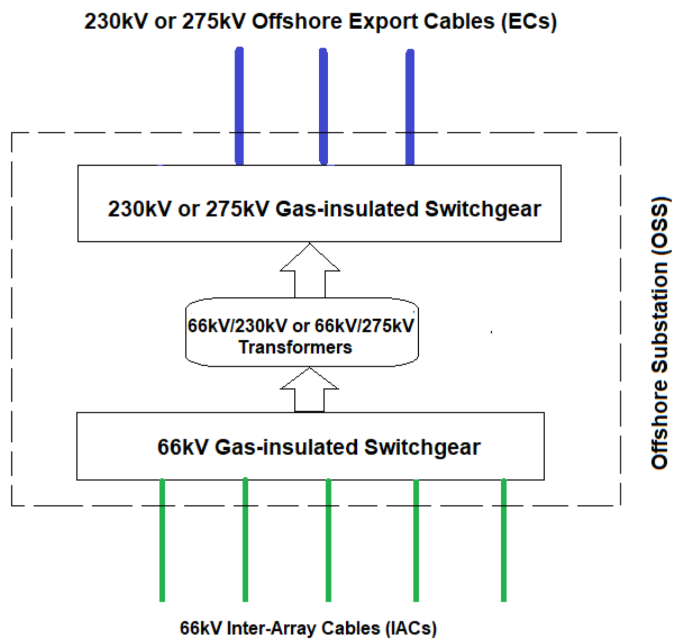

Figure 4-134 Sample Configuration for Offshore Substations with AC Cables

At this voltage, the electricity is carried from a 230 kV or 275 kV kV Gas-insulated Switchgear through 230 kV or 275 kV offshore export cables to an onshore substation. The simulated OSS included incoming 66 kV inter-array cables, 66 kV Gas-insulated Switchgear, 230 kV or 275 kV kV Gas-insulated Switchgear, outgoing 230 kV or 275 kV offshore export cables and two 230 kV or 275 kV OSS inter-link[5] cables. Magnetic fields are calculated at sea level, Cellar Deck, Cable Deck, Main Deck, Utility Deck, and Roof Deck.

[5] Atlantic Shores plan to have two interlink cables at EC voltage level carrying 1200 A each between two OSS.

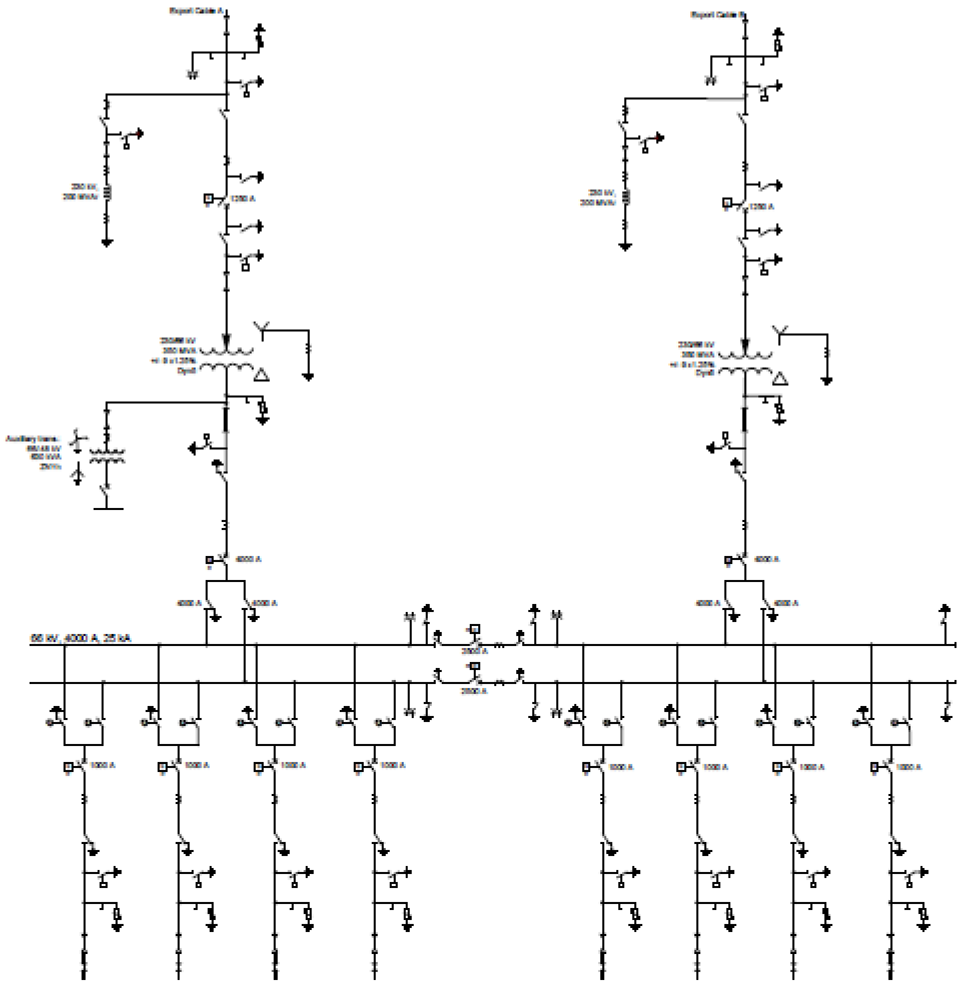

Figure 4-135 Single Line Diagram for HVAC Offshore Substation

Two cases have been simulated for HVAC OSS:

- Case 1 (OSS1-800 MW): the plant generation rating for this case is 800 MW. The OSS includes ten 66 kV inter-array cables, 66 kV Gas-insulated Switchgear, two 66/230 kV or 66/275 kV transformers, 230 kV or 275 kV Gas-insulated Switchgear, two 230 kV or 275 kV 200 MVAr reactors, and four 230 kV or 275 kV offshore export cables (including 2 Interlink cables).
- Case 2 (OSS2-1200 MW): the plant generation rating for this case is 1200 MW. The OSS includes sixteen 66 kV inter-array cables, 66 kV Gas-insulated Switchgear, three 66/230 kV or 66/275 kV transformers, 230 kV or 275 kV Gas-insulated Switchgear, three 230 kV or 275 kV 200 MVAr reactors, and five 230 kV or 275 kV offshore export cables (including 2 Interlink cables).

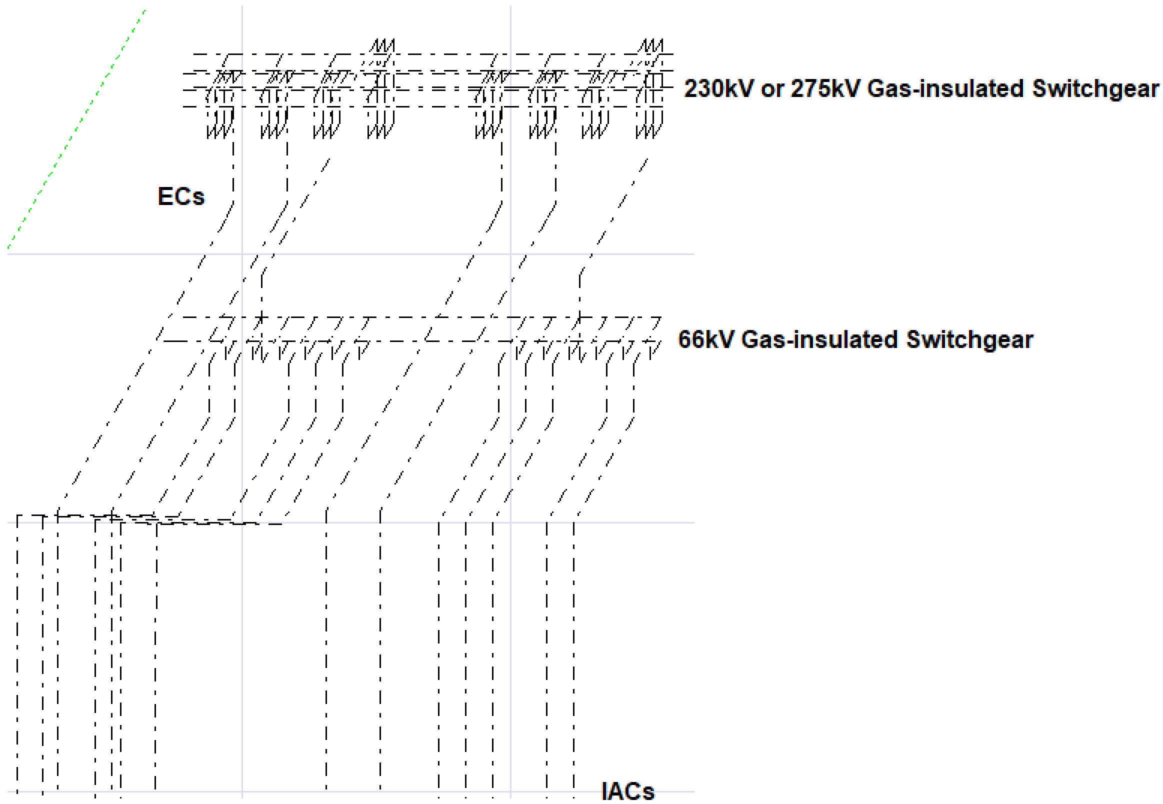

Figure 4-136 OSS1-800 MW CDEGS Model

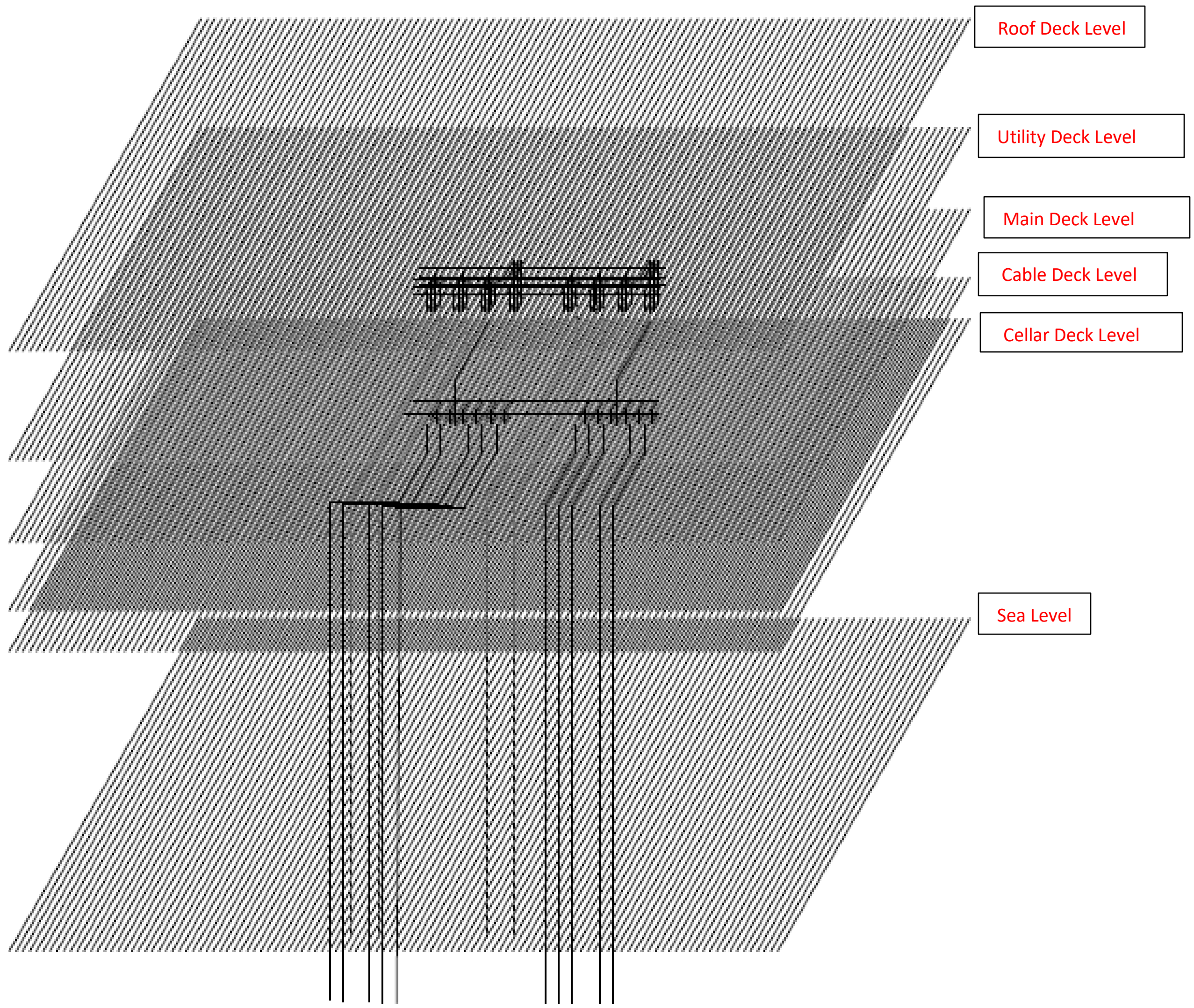

Figure 4-137 OSS1-800 MW CDEGS Model with Deck Profiles

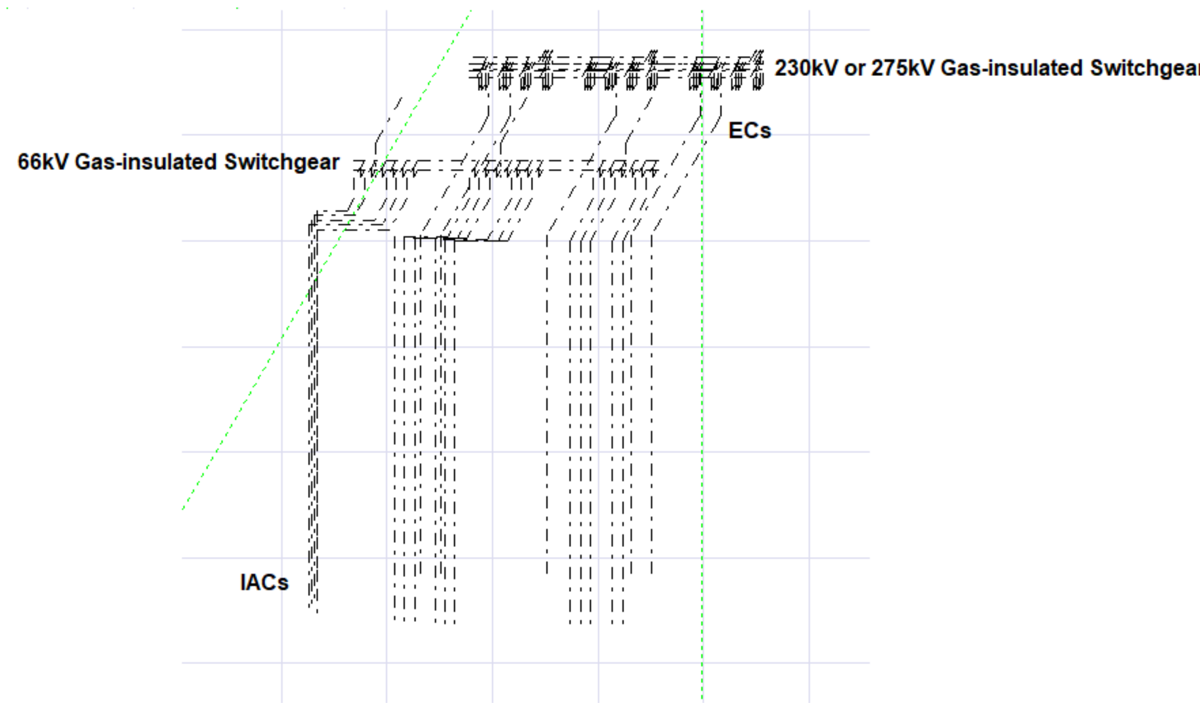

Figure 4-138 OSS2-1200 MW CDEGS Model

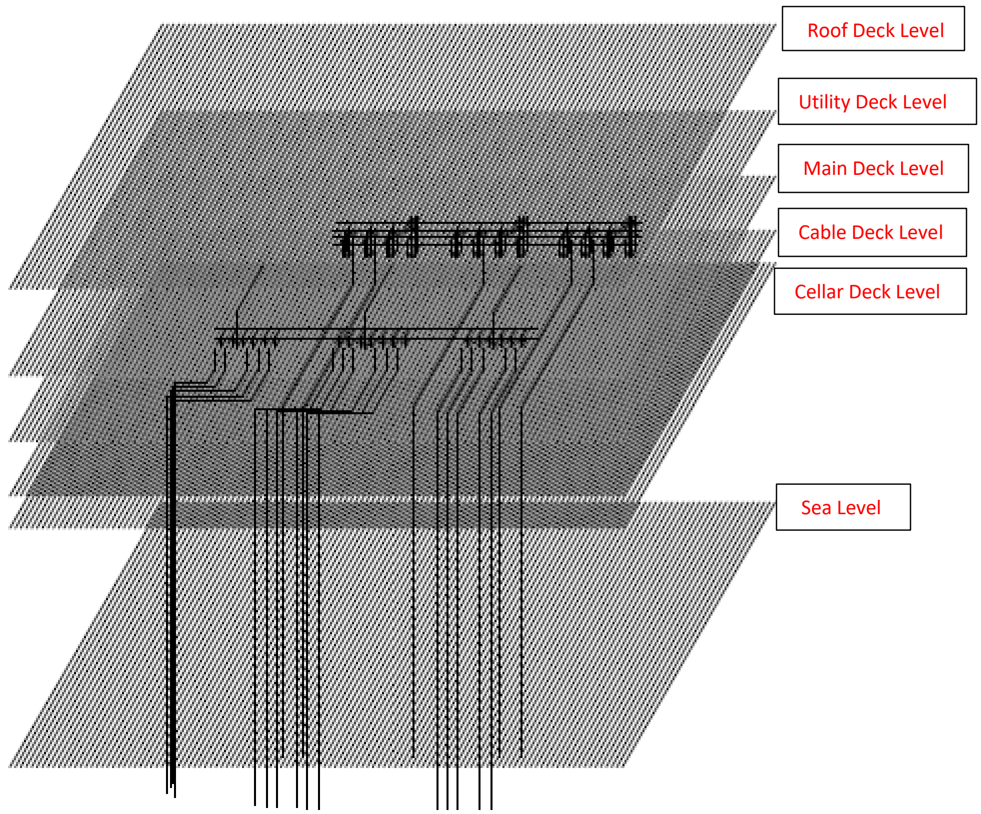

Figure 4-139 OSS2-1200 MW CDEGS Model with Deck Profiles

The results for Case 1 and Case 2 are listed in Table 4-1. The graphical results are presented in the following sections 4.2.1.1.1 and 4.2.1.1.2.

Table 4-1 Results Summary for Case 1(OSS1-800 MW) and Case 2 (OSS2-1000 MW)

Location of Calculation	Peak Magnetic Field (A/m) for Case 1(OSS1-800 MW)	Peak Magnetic Field (A/m) for Case 2(OSS2-1200 MW)	Distance from energized conductor at which magnetic field drops below limits [6]	
			OSS1 (800 MW)	OSS2 (1200 MW)
Sea Level	1000.46	971.56	1.31 feet (0.4 m) from ECs 1 feet (0.3 m) from IACs	1 feet (0.3 m) from ECs 1 feet (0.3 m) from IACs
Cellar Deck Level	480.79	389.68	-	-
Cable Deck Level	649.66	389.18	-	-
Main Deck Level	990.82	1181.50	1 feet (0.3 m) from 230 kV or 275 kV Gas-insulated Switchgear bus	1.31 feet (0.4 m) from 230 kV or 275 kV Gas-insulated Switchgear bus
Utility Deck Level	116.89	136.31	-	-
Roof Deck Level	6.83	1.70	-	-

It is important to mention that the peak magnetic field violates (160 A/m and 800 A/m) maximum allowable public and occupational limits at sea level and main deck level respectively (refer to Table 1-2). However, those peaks occur right at the cables or Gas-insulated Switchgear buses only and the magnetic field decays quickly while moving away from the energized conductor. SNC Lavalin analyzed the magnetic field profiles to determine the distance from the energized conductor at which the magnetic field value fall below the respective limits. The results of this analysis are indicated in Table 4-1.

The magnetic field in other areas is within maximum allowable limit (refer to Figures 4-140, 4-146, 4-152, and 4-158). The magnetic field at other deck levels (Cellar Deck, Cable Deck, Utility Deck, Roof Deck) is within its 800 A/m maximum occupational allowable limit.

Comparing calculated magnetic fields with the 160 A/m maximum allowable limit for general public is not of concern as it is anticipated that the OSS decks will be accessed only by trained workers. The magnetic fields at the sea level can be compared with 160 A/m limit as the OSS can be approached at sea level by general public. It can be seen that at the locations other than right at the cables at sea level, the magnetic fields are lower than 160 A/m.

[6] Refer to Appendix A

4.2.1.1.1 Results for Case 1 (OSS1-800 MW)

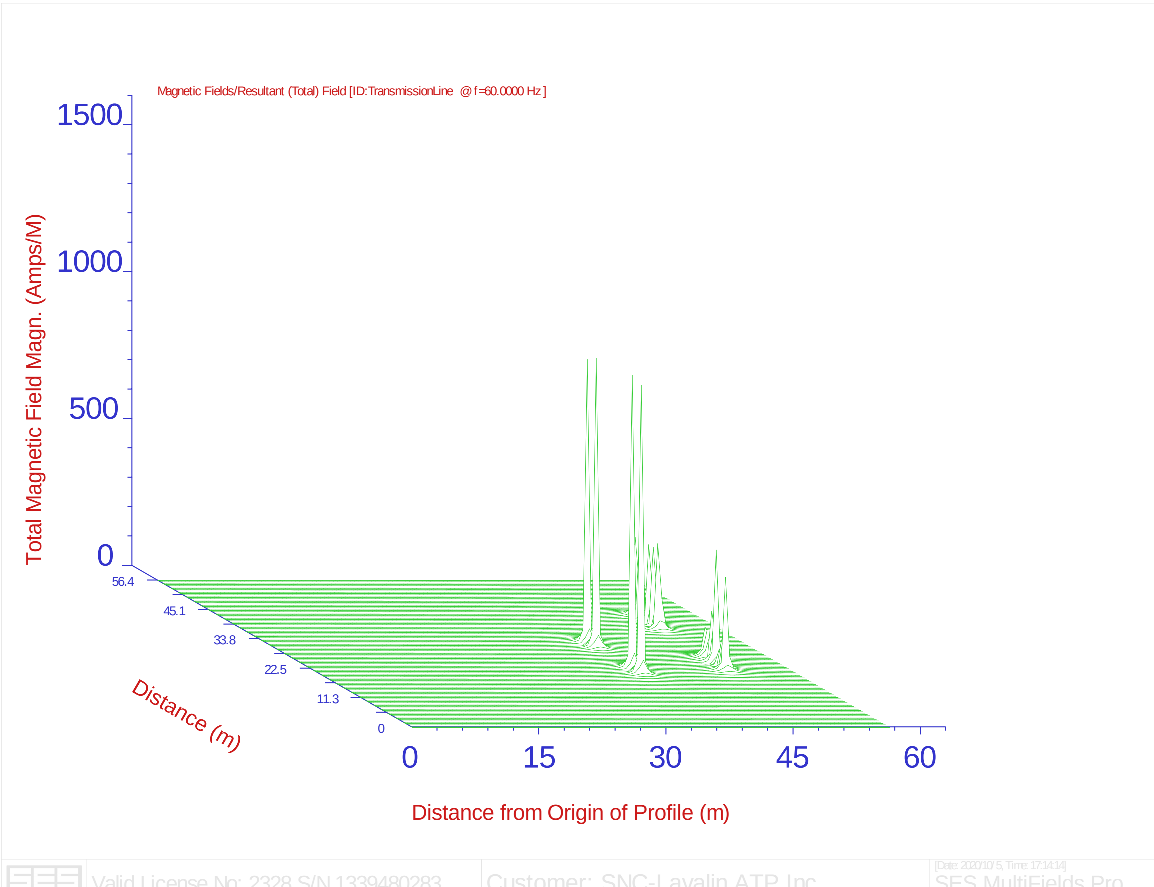

Figure 4-140 3D Magnetic Field Result of OSS1-800 MW Case at sea level

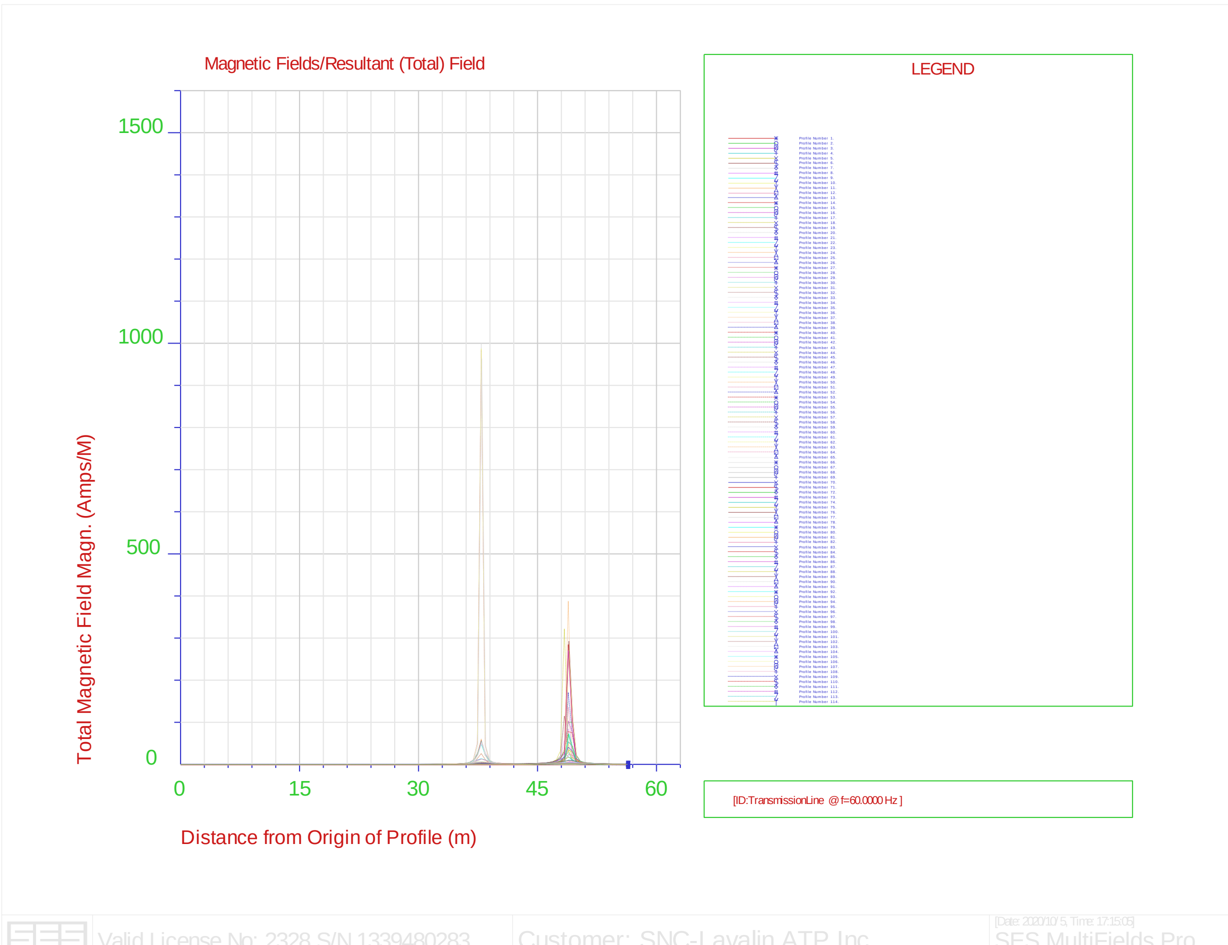

Figure 4-141 2D Magnetic Field Result of OSS1-800 MW Case at sea level

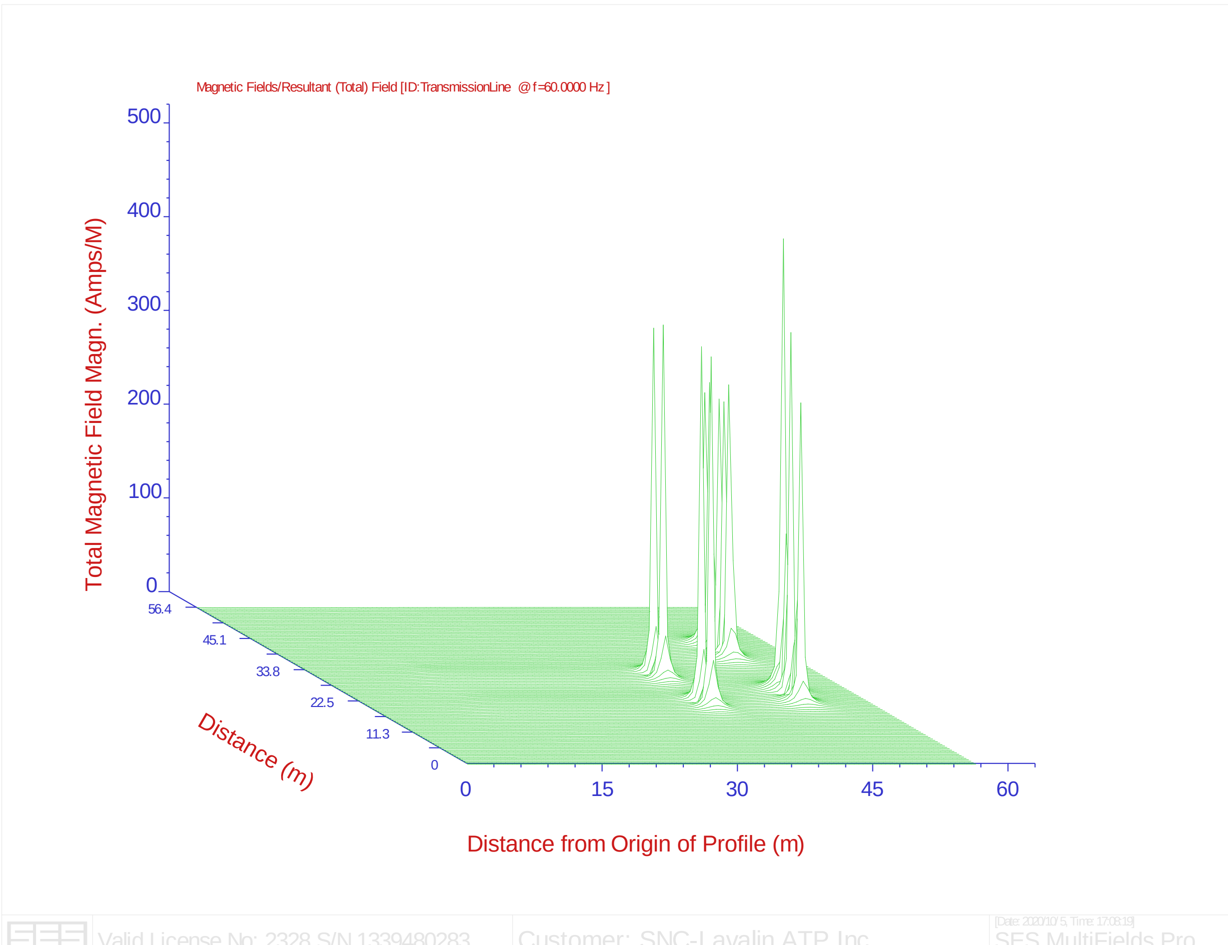

Figure 4-142 3D Magnetic Field Result of OSS1-800 MW Case at Cellar Deck Level

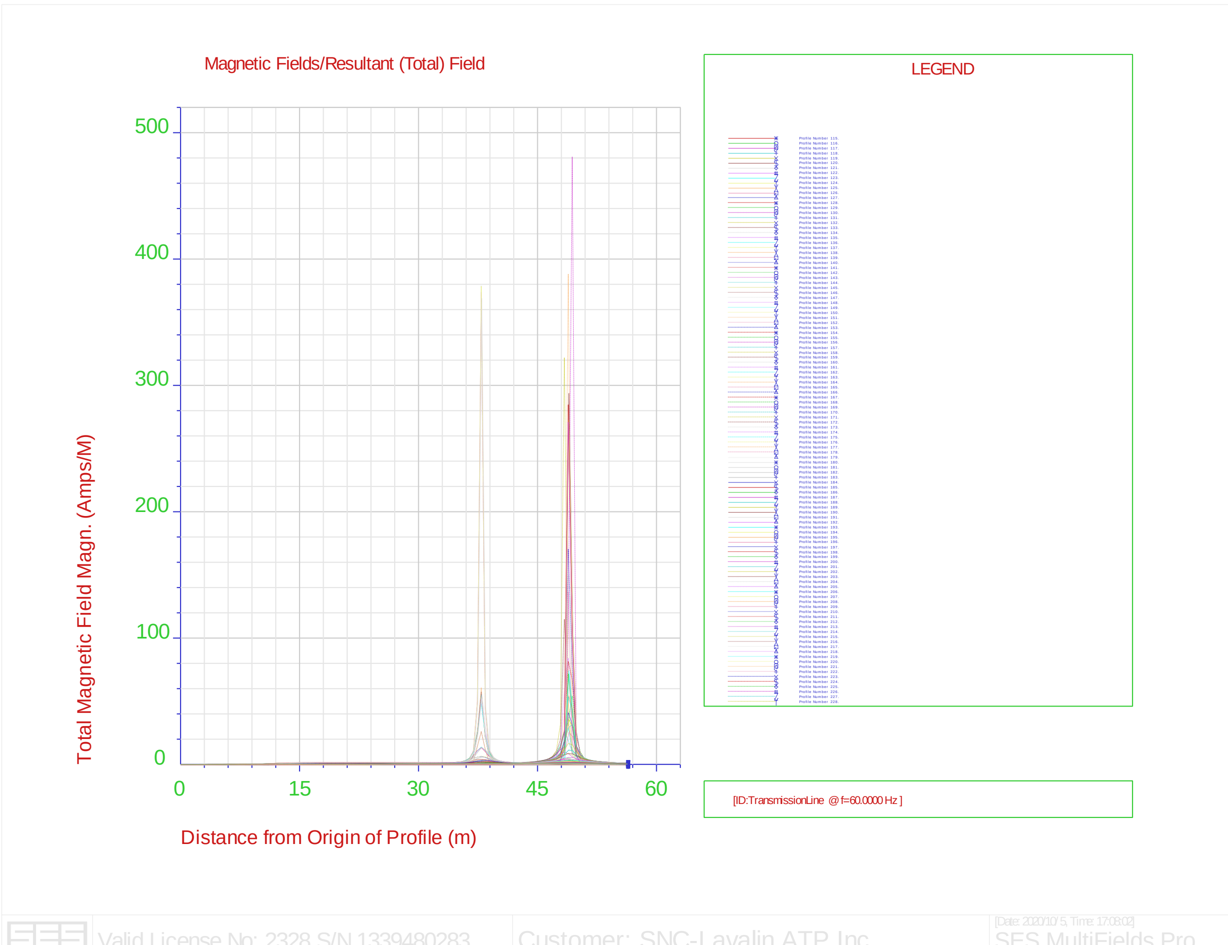

Figure 4-143 2D Magnetic Field Result of OSS1-800 MW Case at Cellar Deck Level

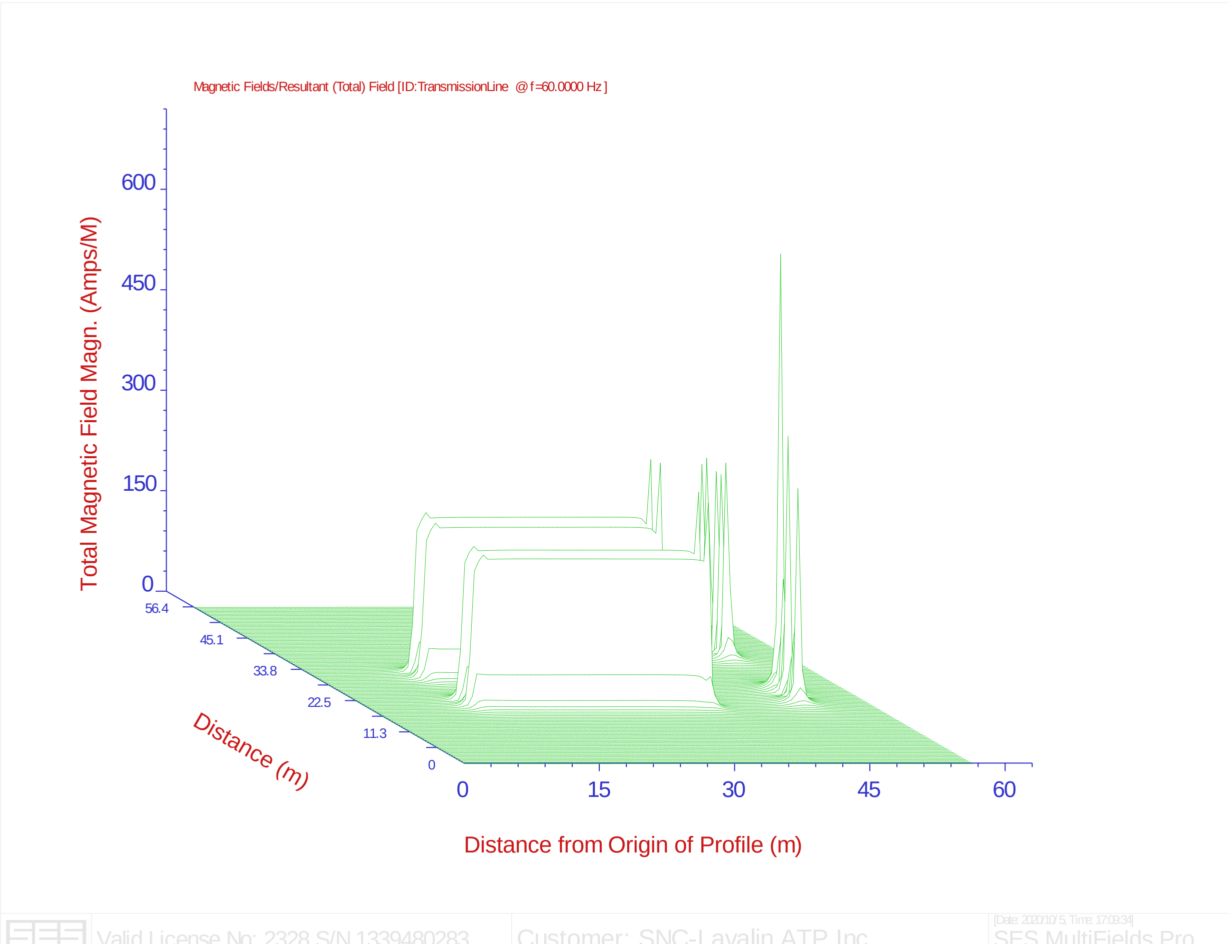

Figure 4-144 3D Magnetic Field Result of OSS1-800 MW Case at Cable Deck Level

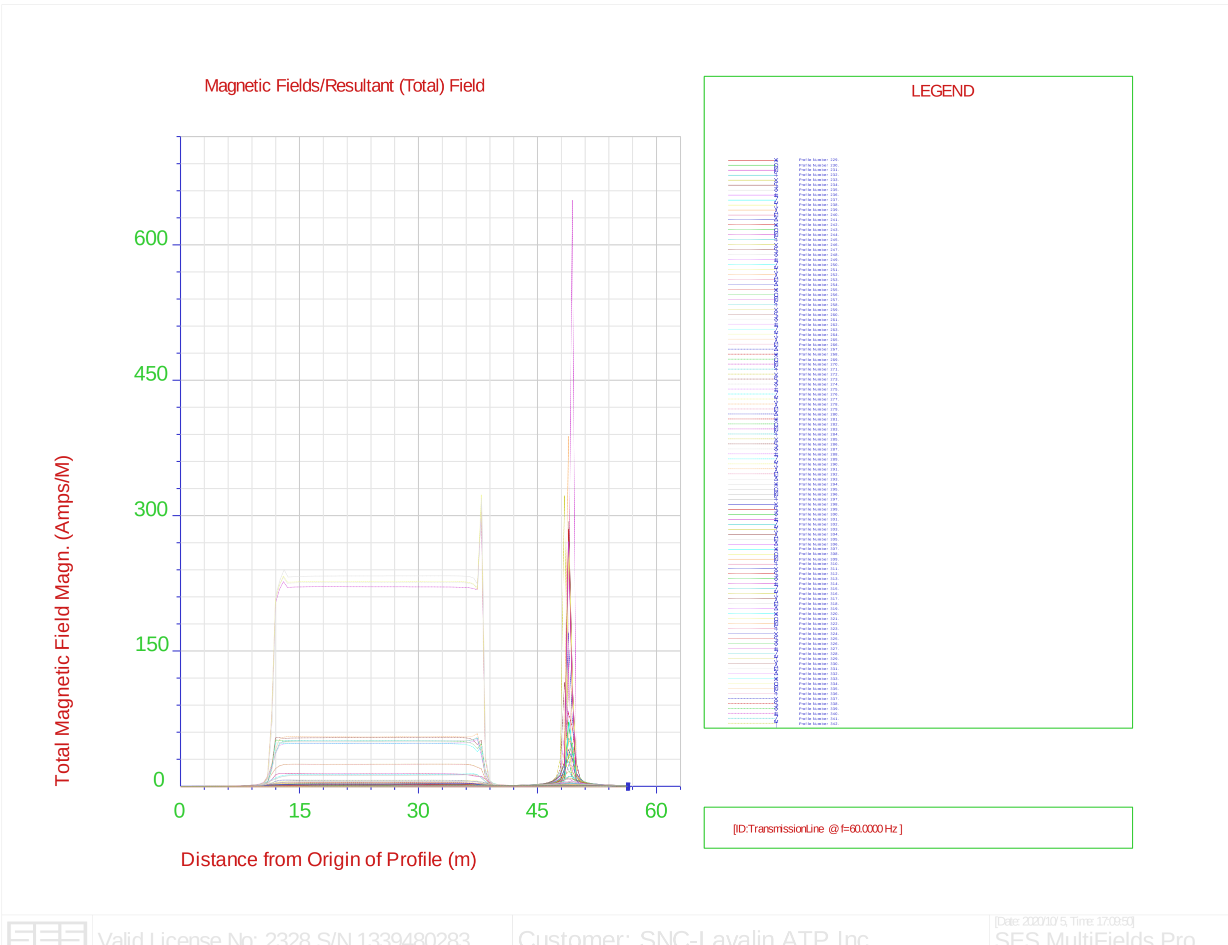

Figure 4-145 2D Magnetic Field Result of OSS1-800 MW Case at Cable Deck Level

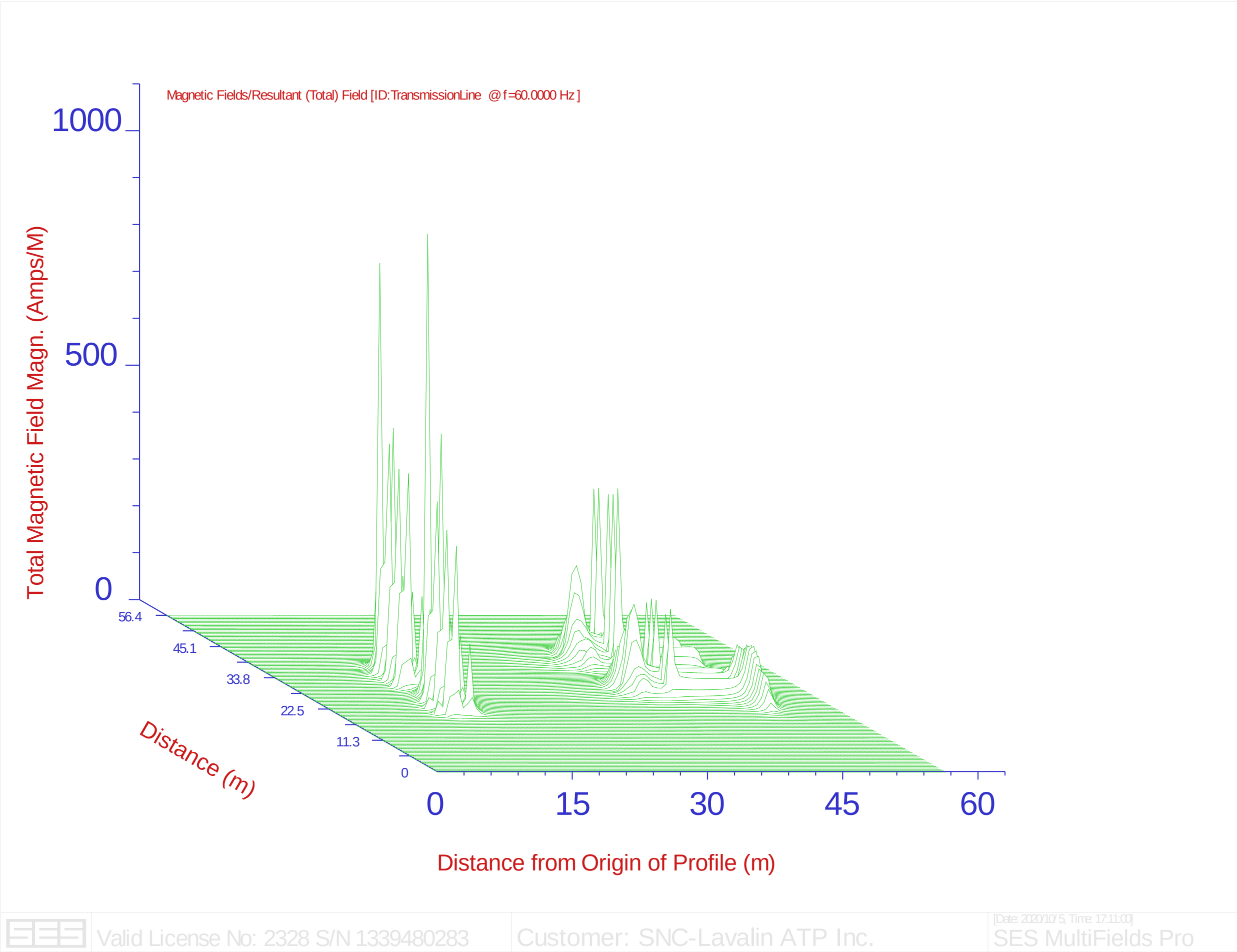

Figure 4-146 3D Magnetic Field Result of OSS1-800 MW Case at Main Deck Level

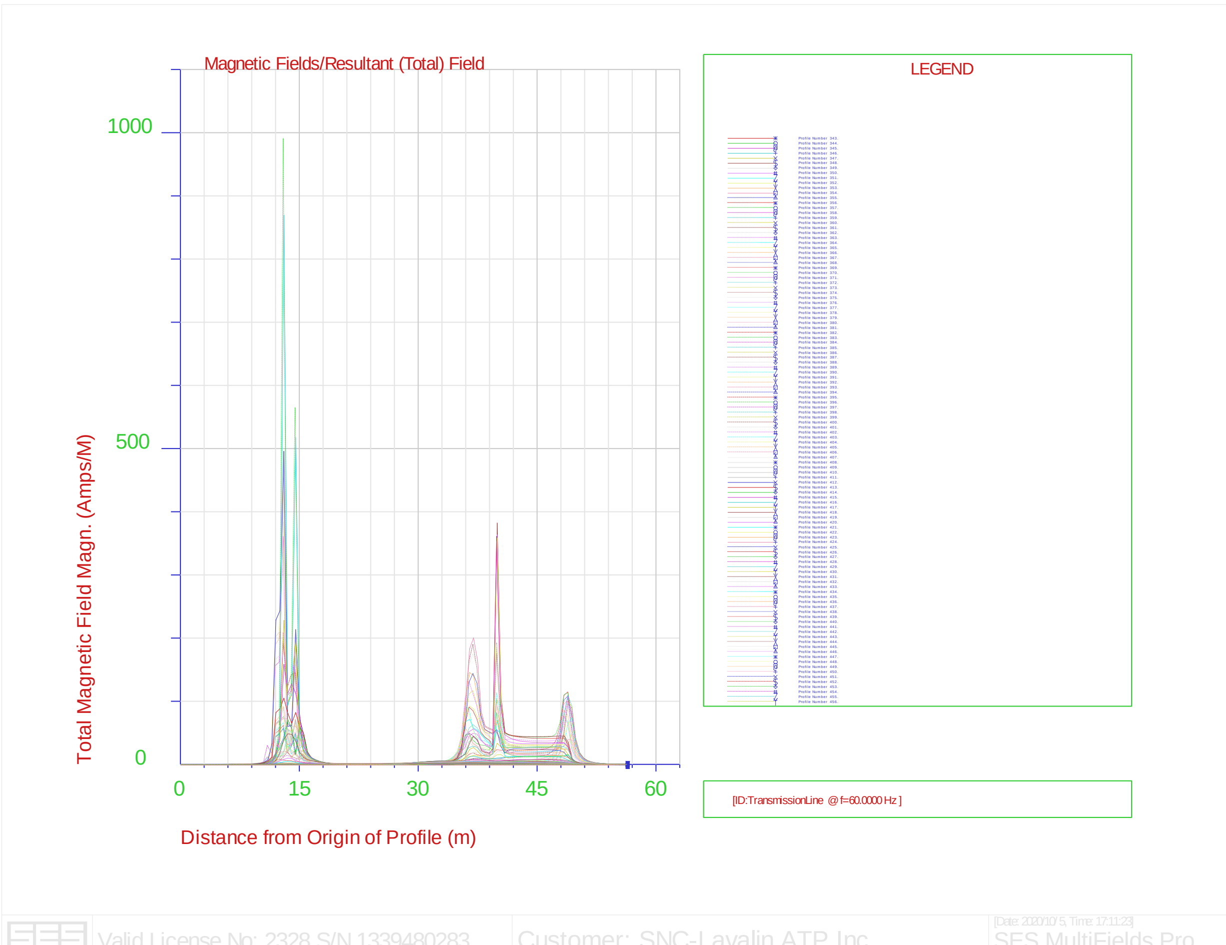

Figure 4-147 2D Magnetic Field Result of OSS1-800 MW Case at Main Deck Level

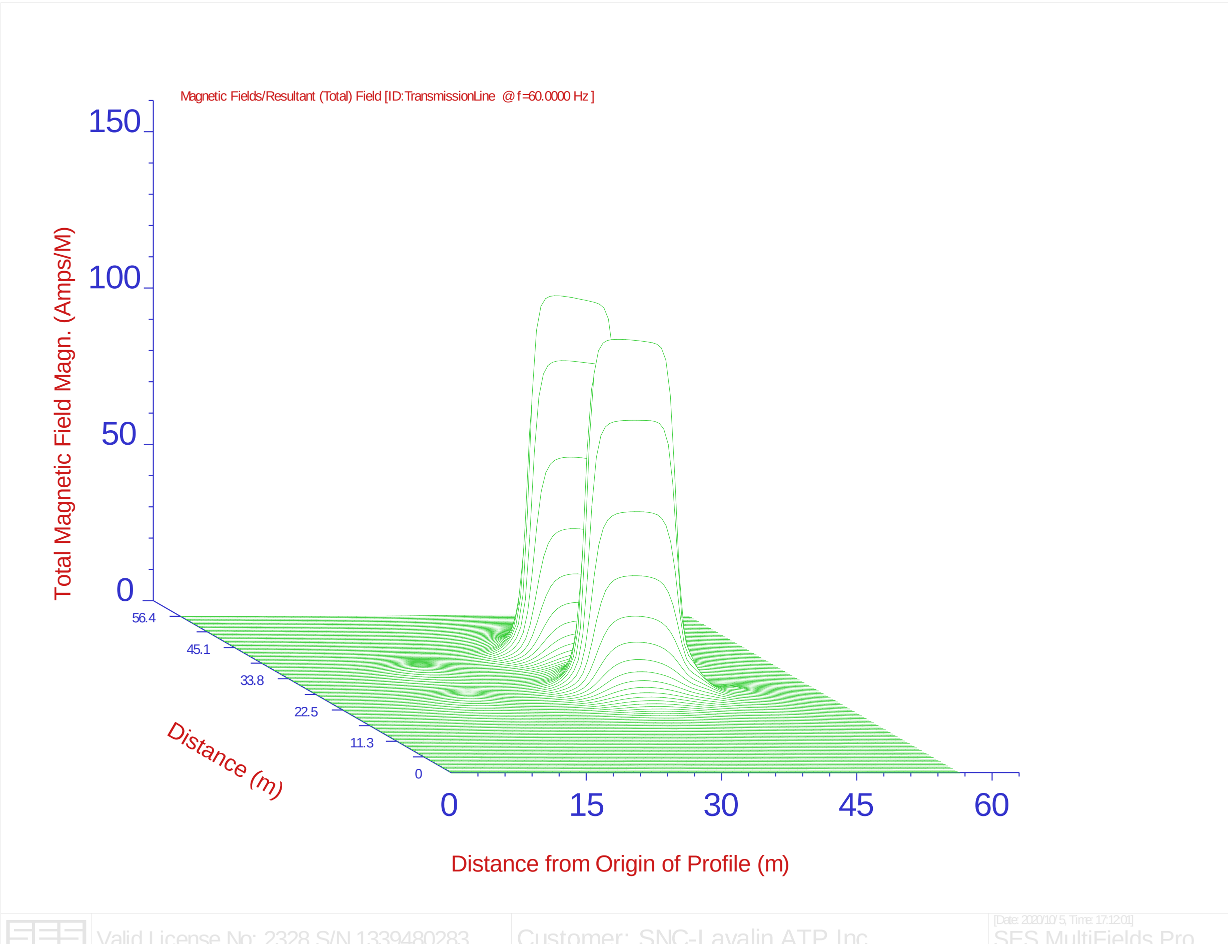

Figure 4-148 3D Magnetic Field Result of OSS1-800 MW Case at Utility Deck Level

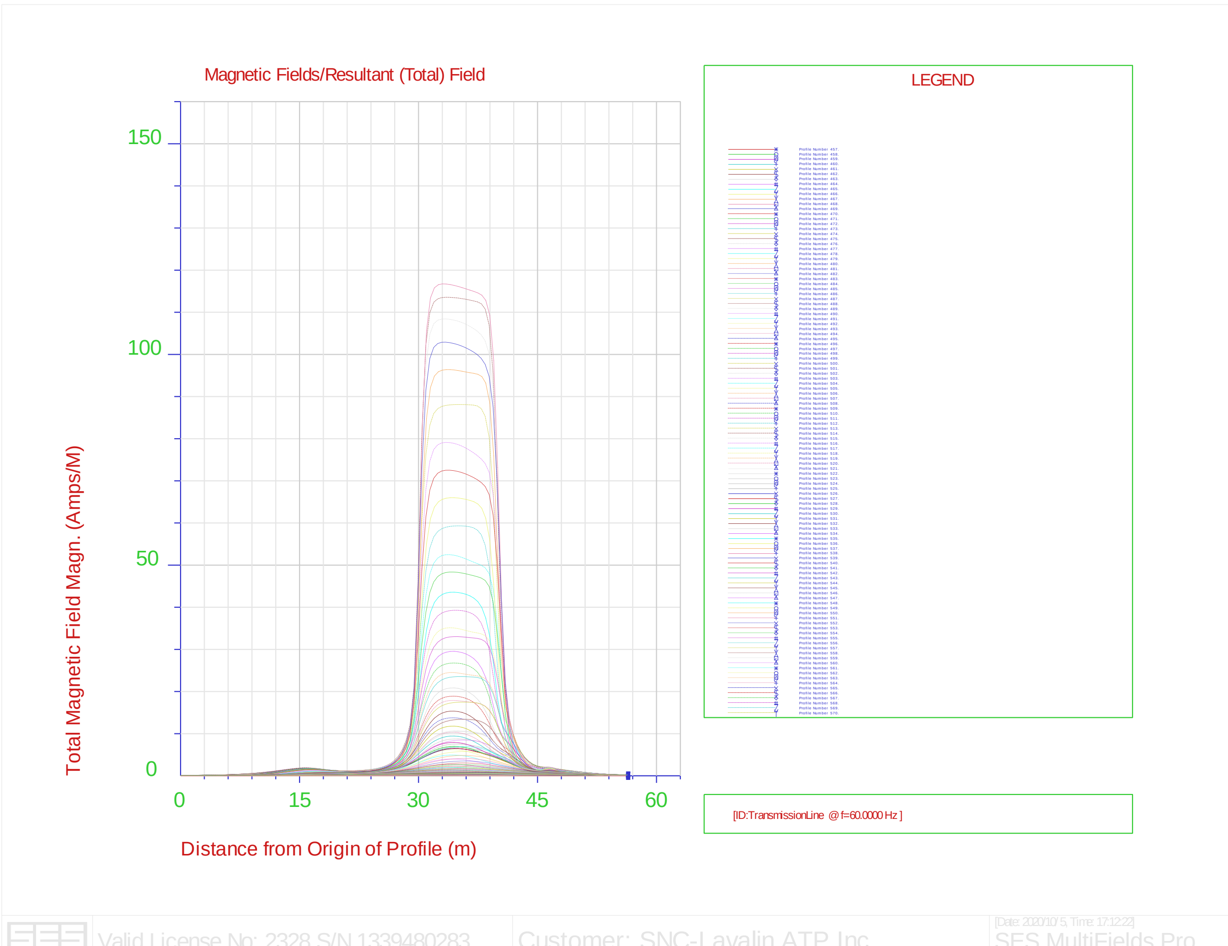

Figure 4-149 2D Magnetic Field Result of OSS1-800 MW Case at Utility Deck Level

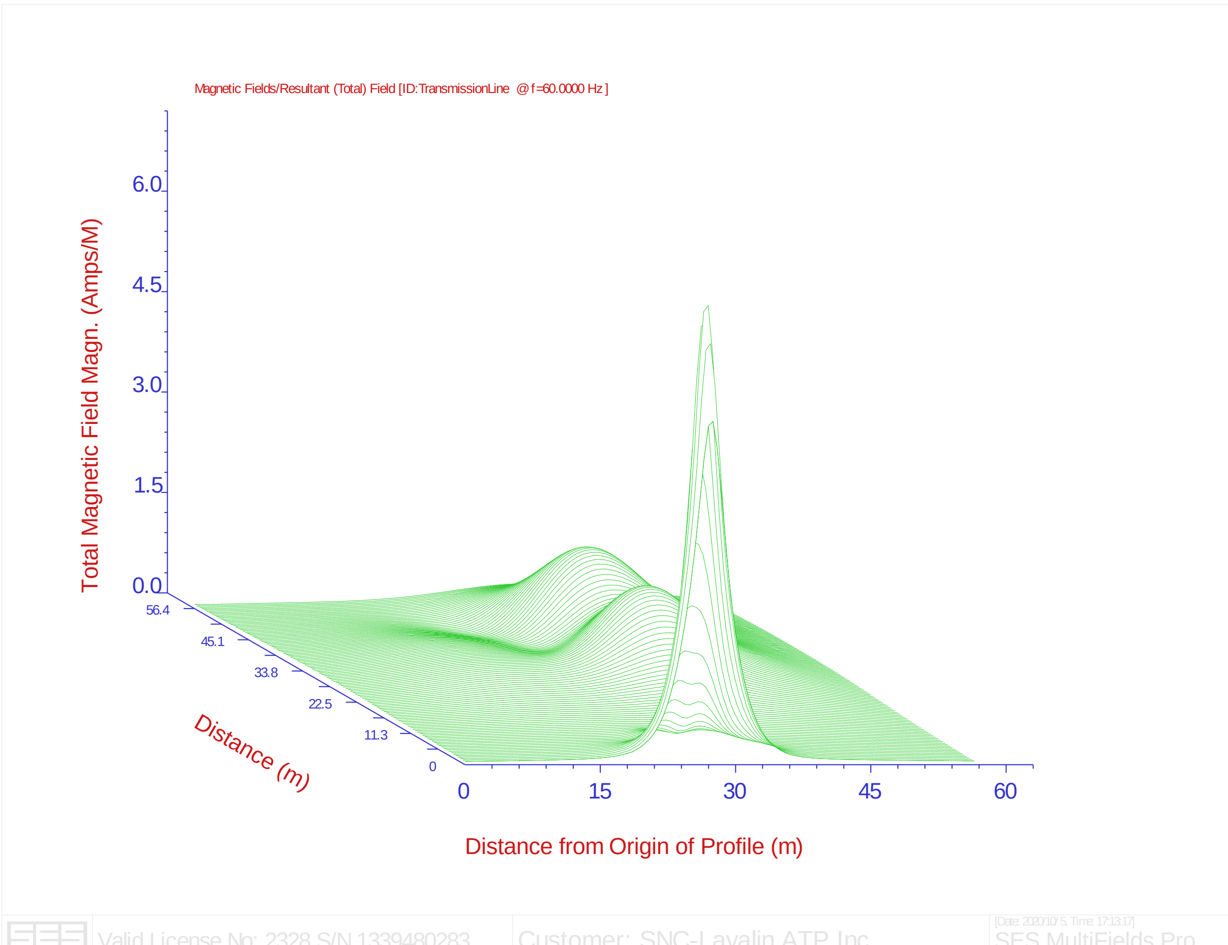

Figure 4-150 3D Magnetic Field Result of OSS1-800 MW Case at Roof Deck Level

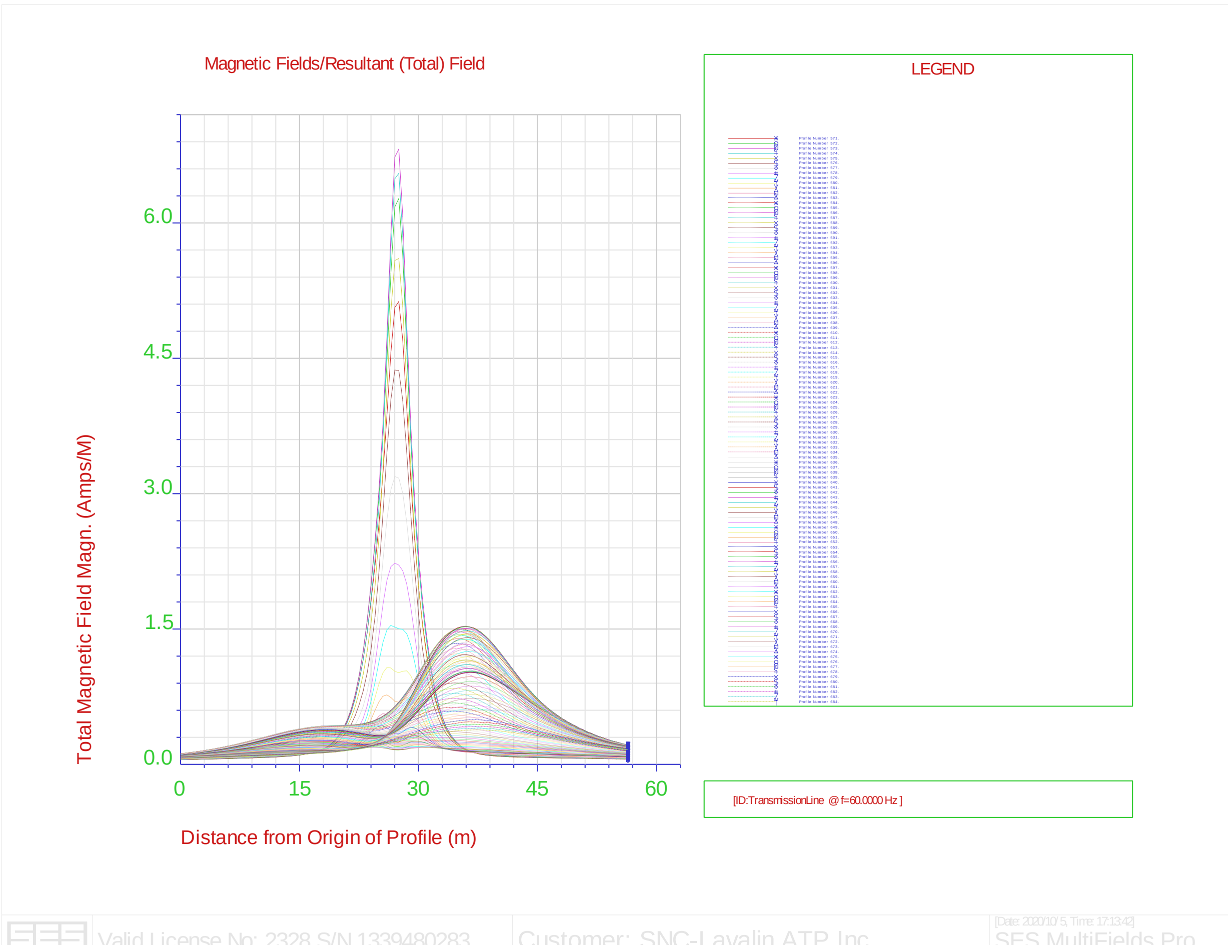

Figure 4-151 2D Magnetic Field Result of OSS1-800 MW Case at Roof Deck Level

4.2.1.1.2 Results for Case 2 (OSS2-1200 MW)

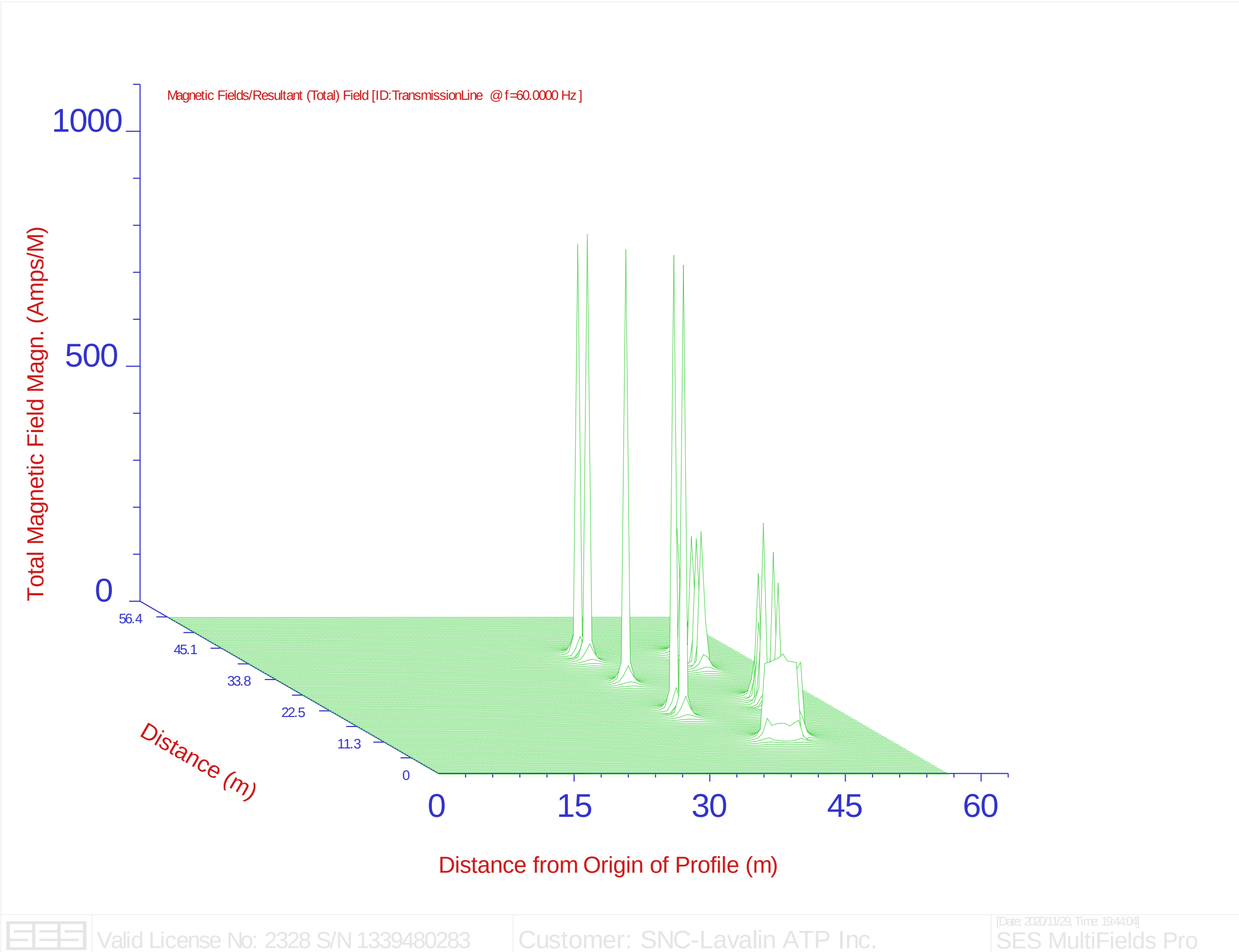

Figure 4-152 3D Magnetic Field Result of OSS2-1200 MW Case at sea level

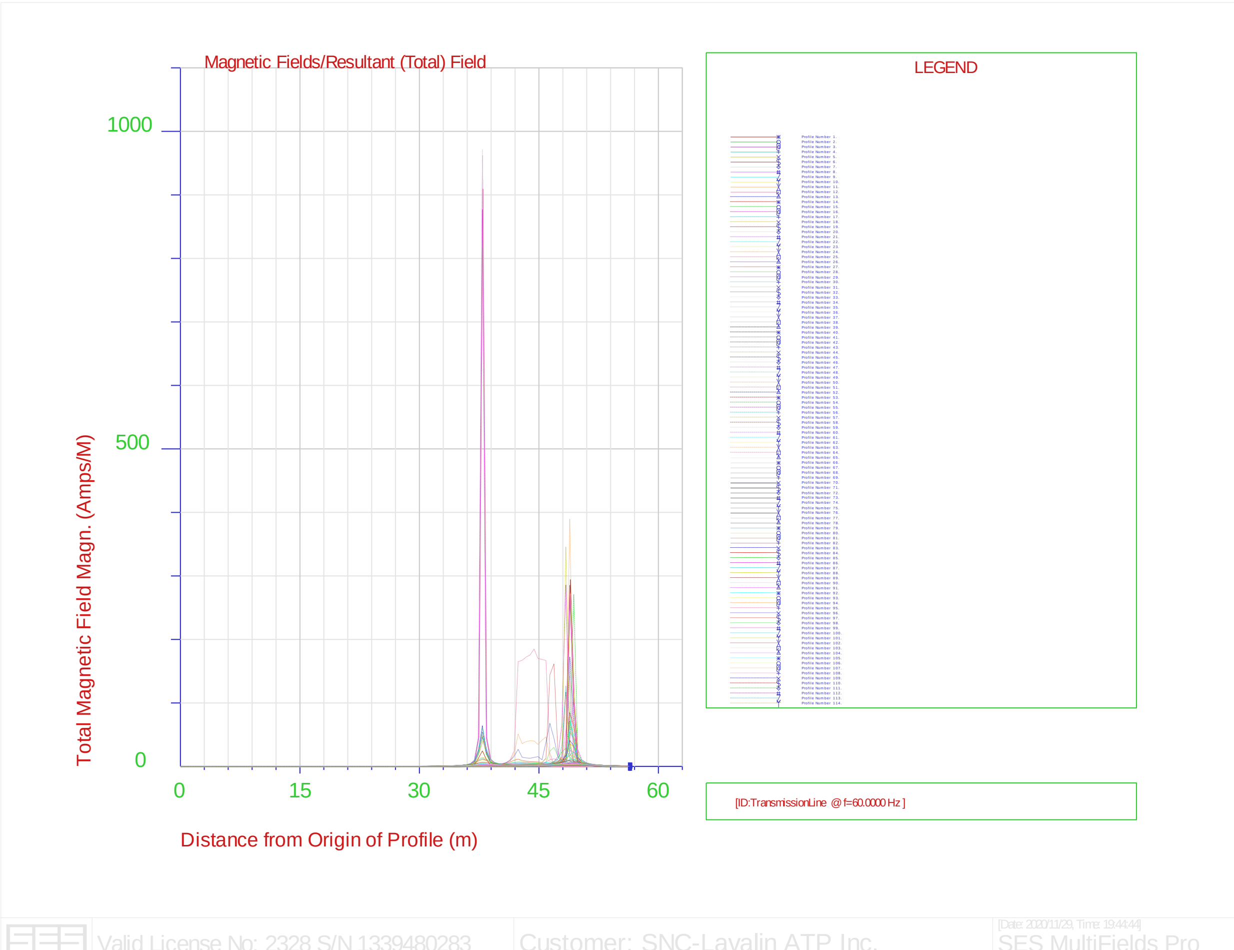

Figure 4-153 2D Magnetic Field Result of OSS2-1200 MW Case at sea level

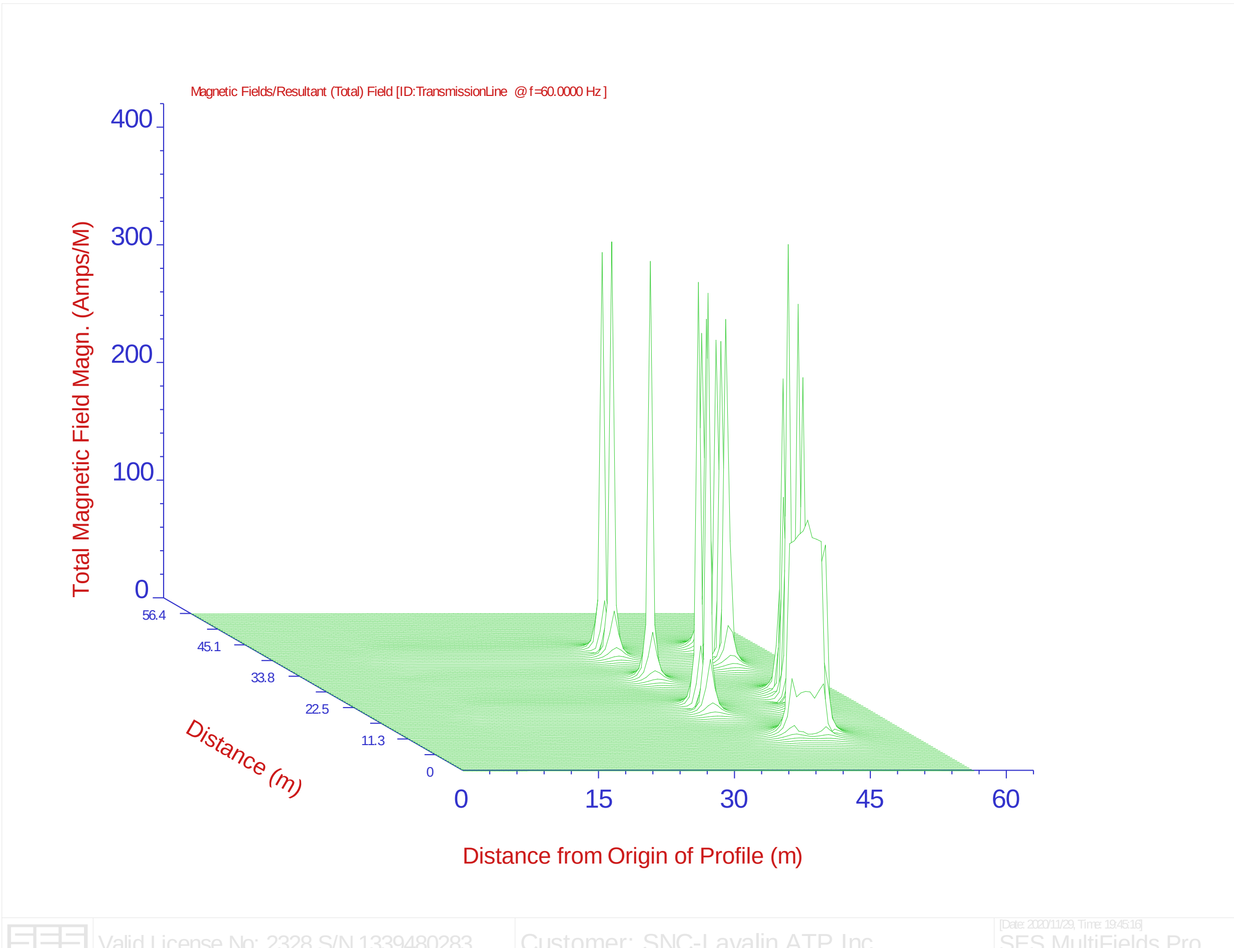

Figure 4-154 3D Magnetic Field Result of OSS2-1200 MW Case at Cellar Deck Level

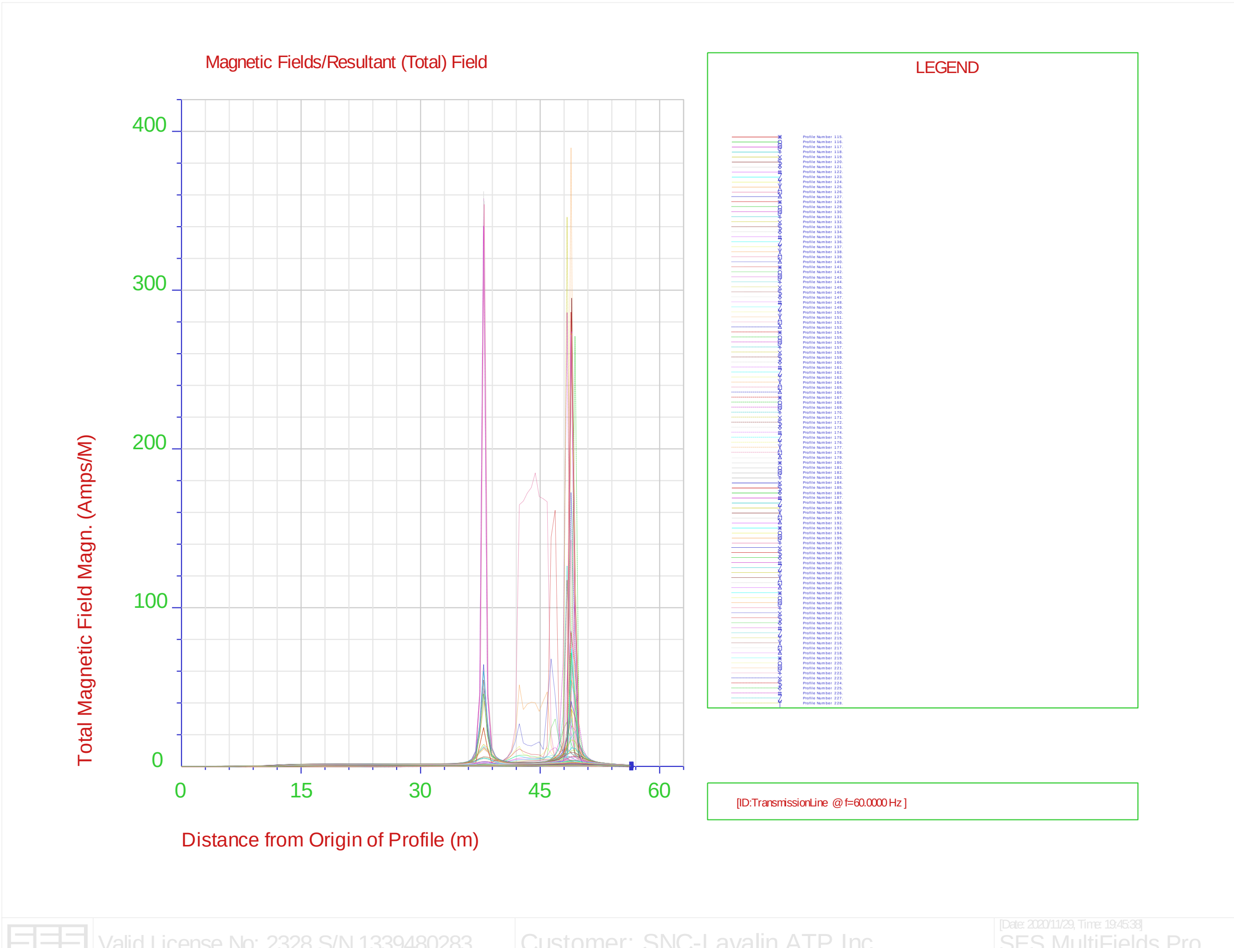

Figure 4-155 2D Magnetic Field Result of OSS2-1200 MW Case at Cellar Deck Level

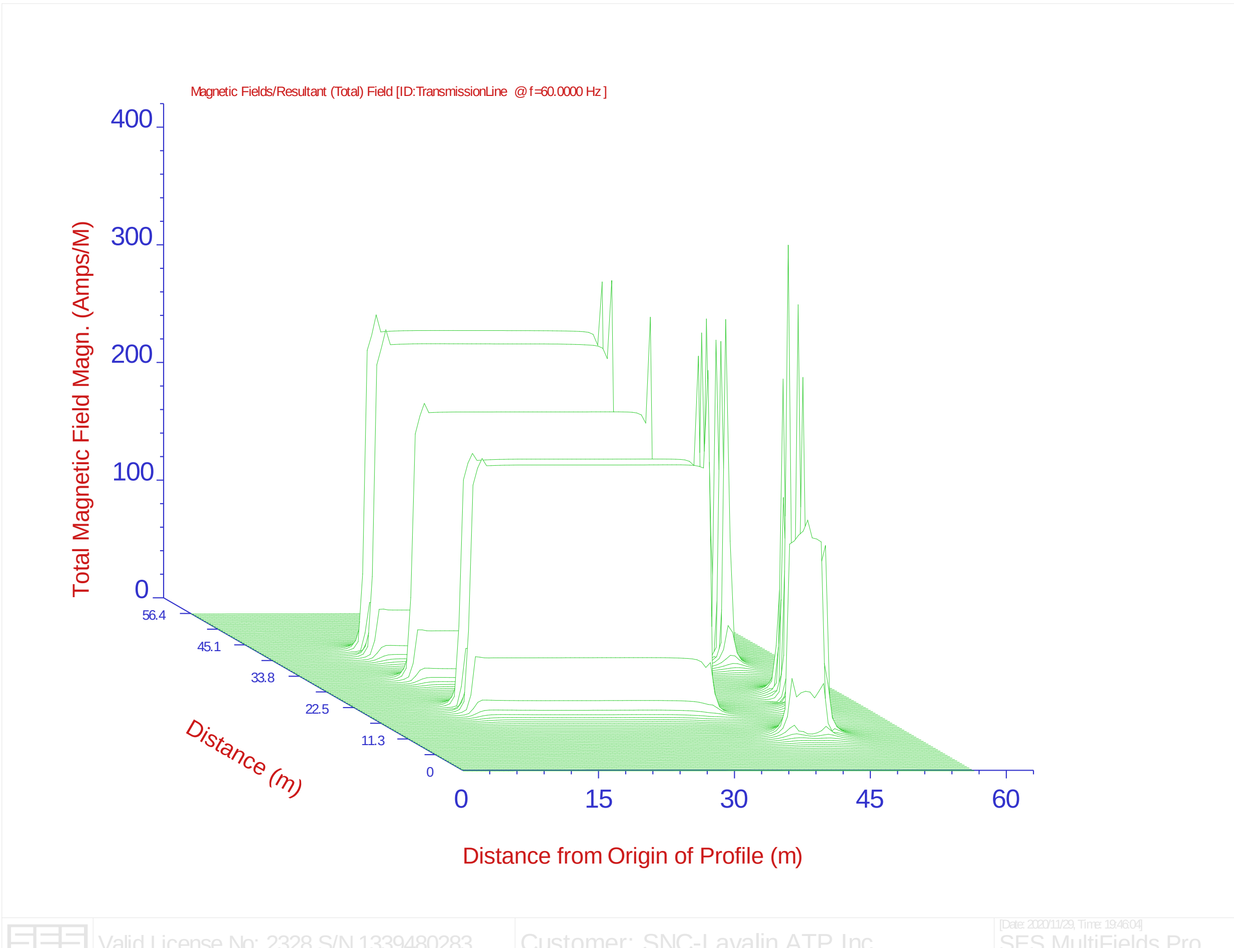

Figure 4-156 3D Magnetic Field Result of OSS2-1200 MW Case at Cable Deck Level

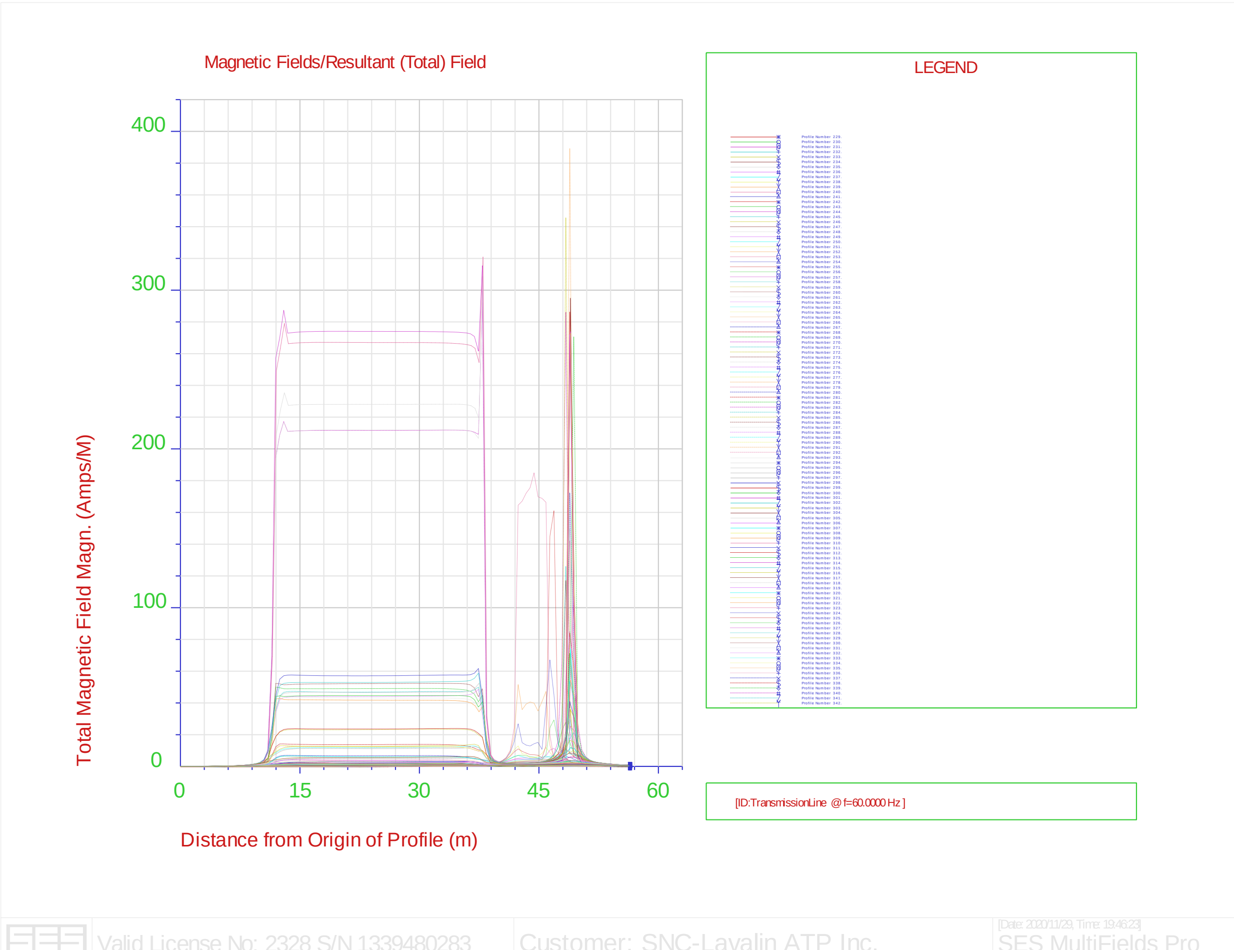

Figure 4-157 2D Magnetic Field Result of OSS2-1200 MW Case at Cable Deck Level

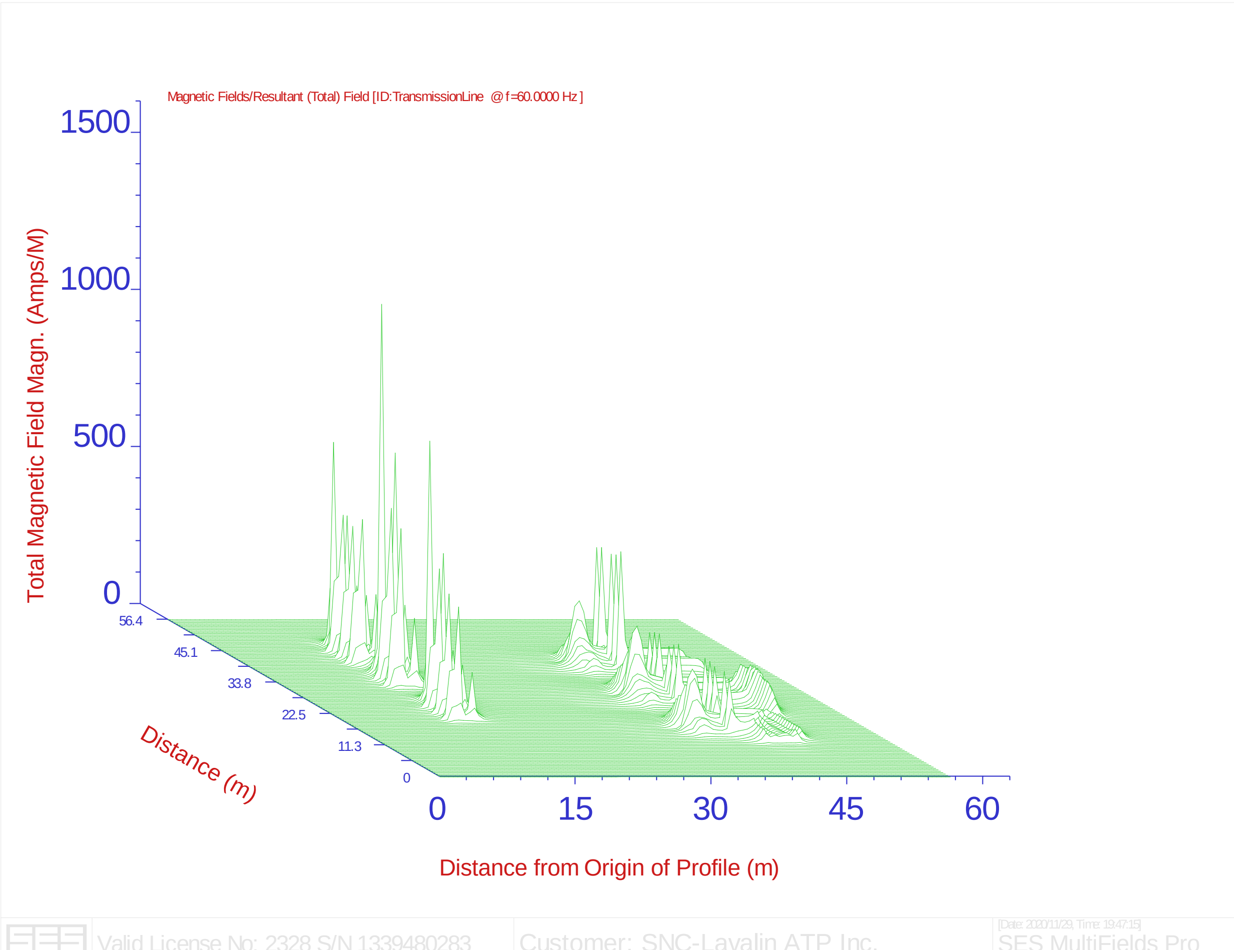

Figure 4-158 3D Magnetic Field Result of OSS2-1200 MW Case at Main Deck Level

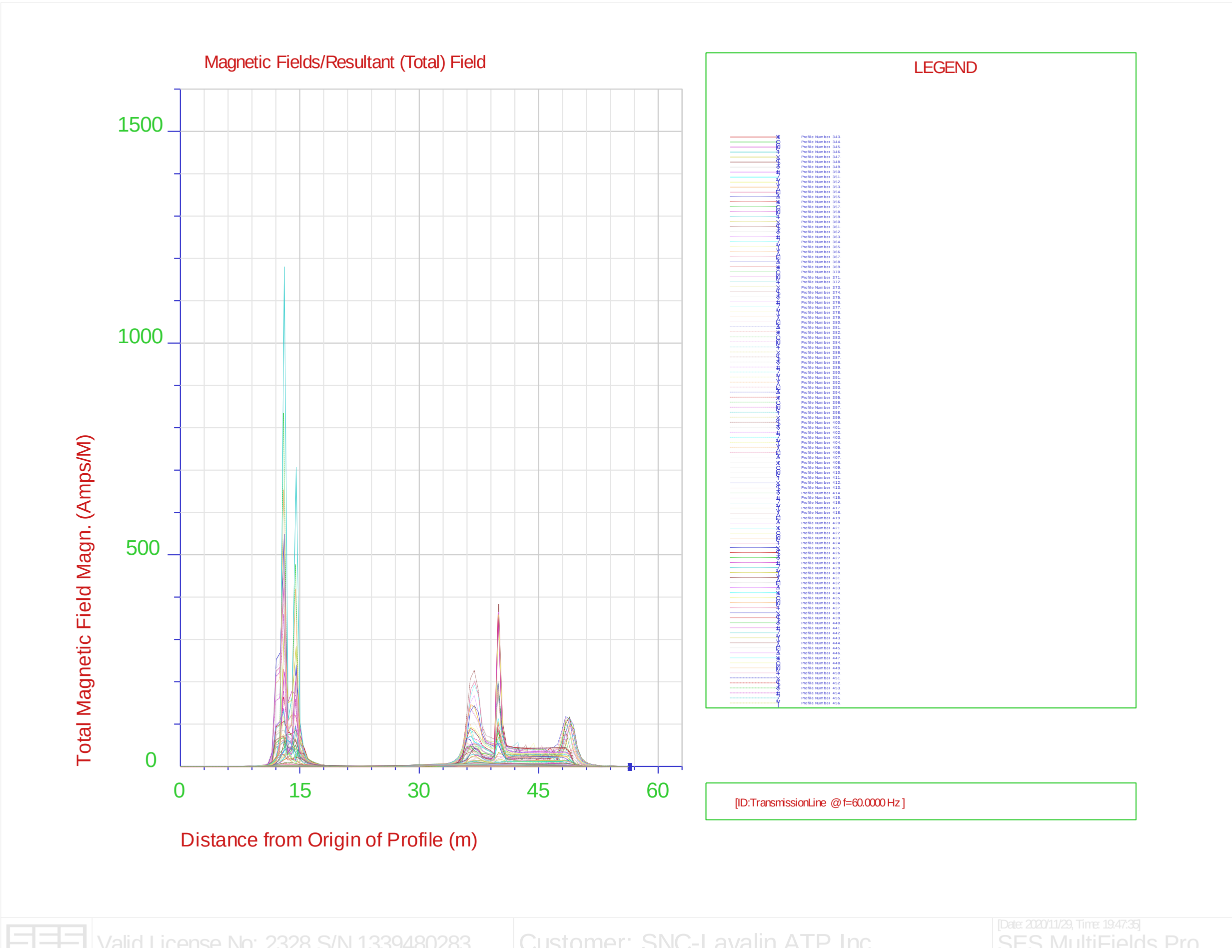

Figure 4-159 2D Magnetic Field Result of OSS2-1200 MW Case at Main Deck Level

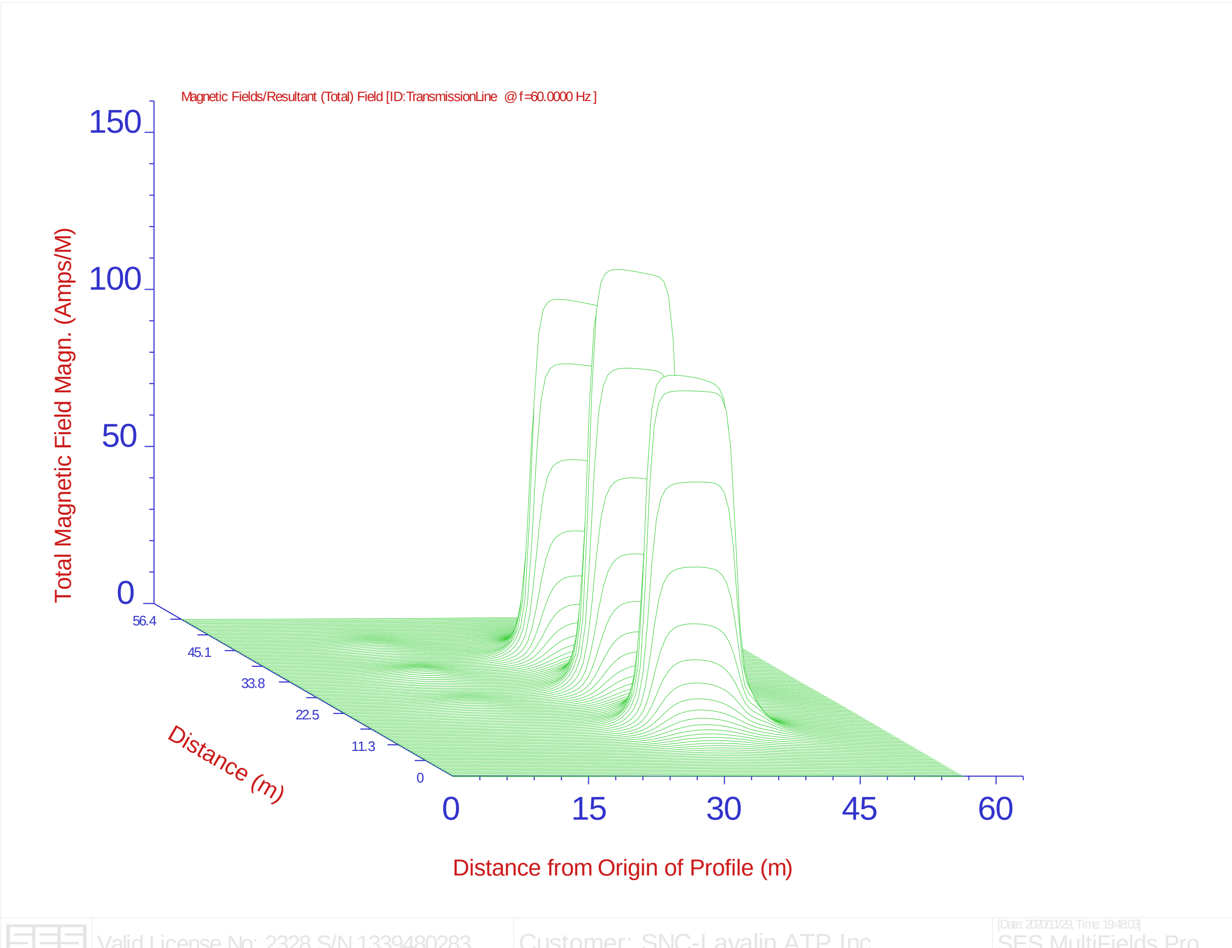

Figure 4-160 3D Magnetic Field Result of OSS2-1200 MW Case at Utility Deck Level

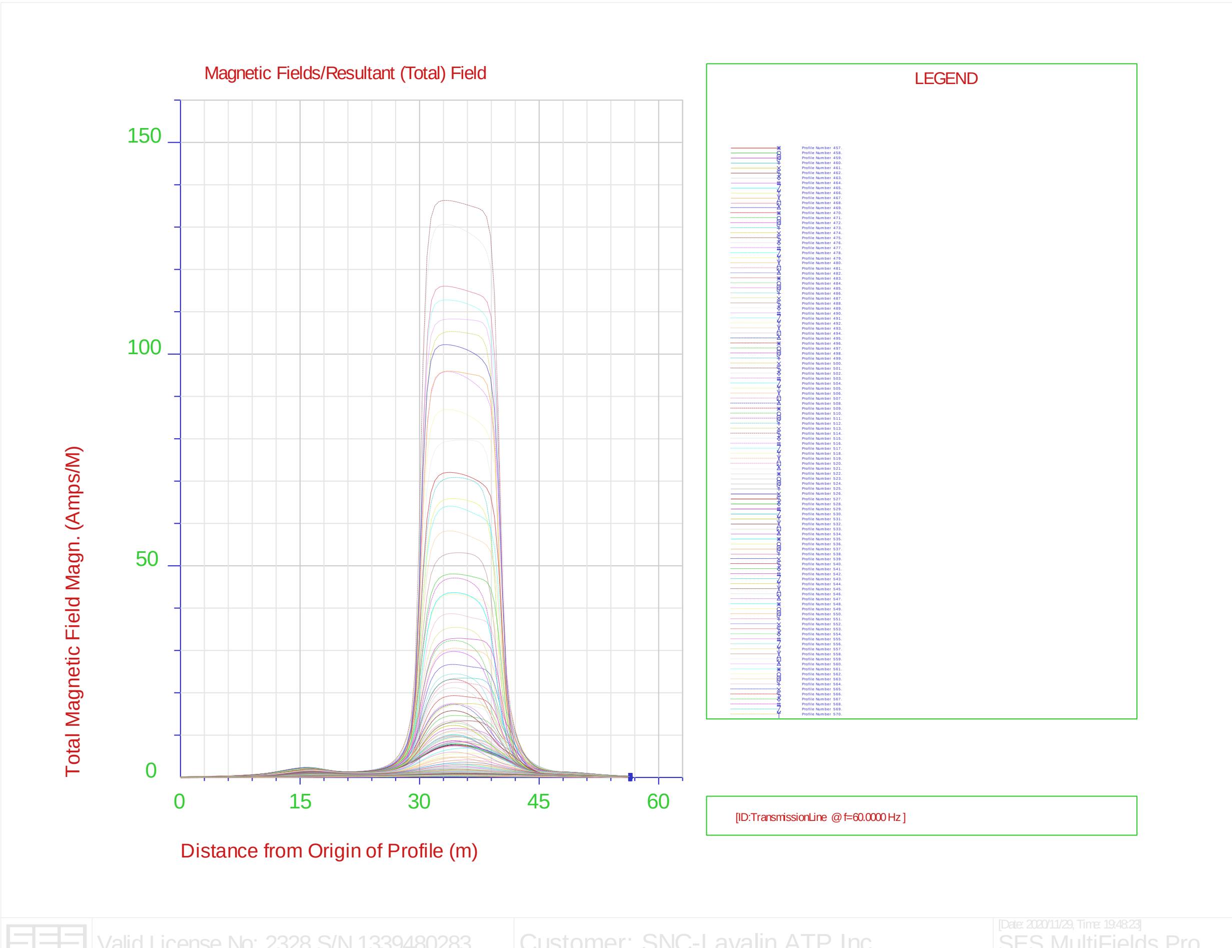

Figure 4-161 2D Magnetic Field Result of OSS2-1200 MW Case at Utility Deck Level

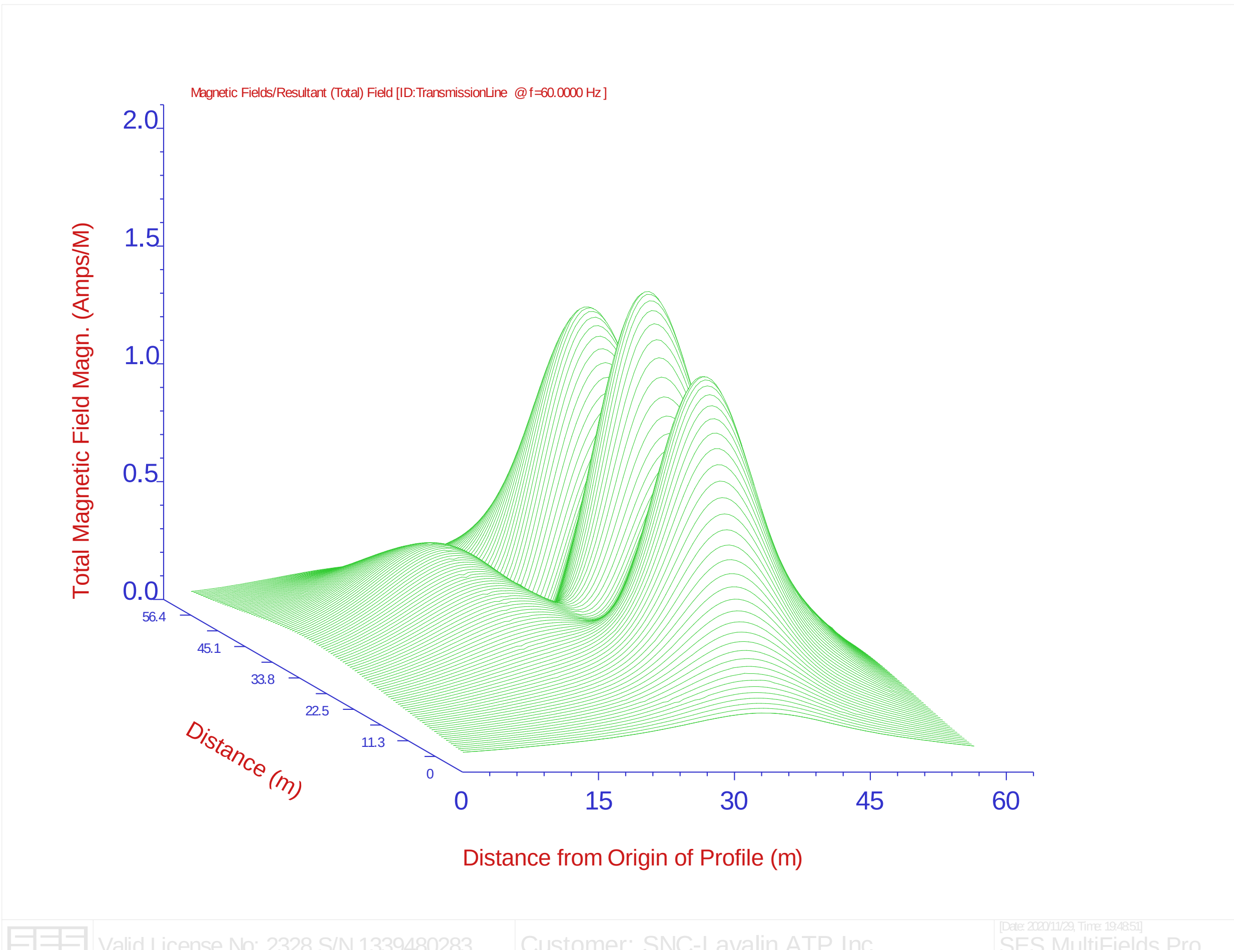

Figure 4-162 3D Magnetic Field Result of OSS2-1200 MW Case at Roof Deck Level

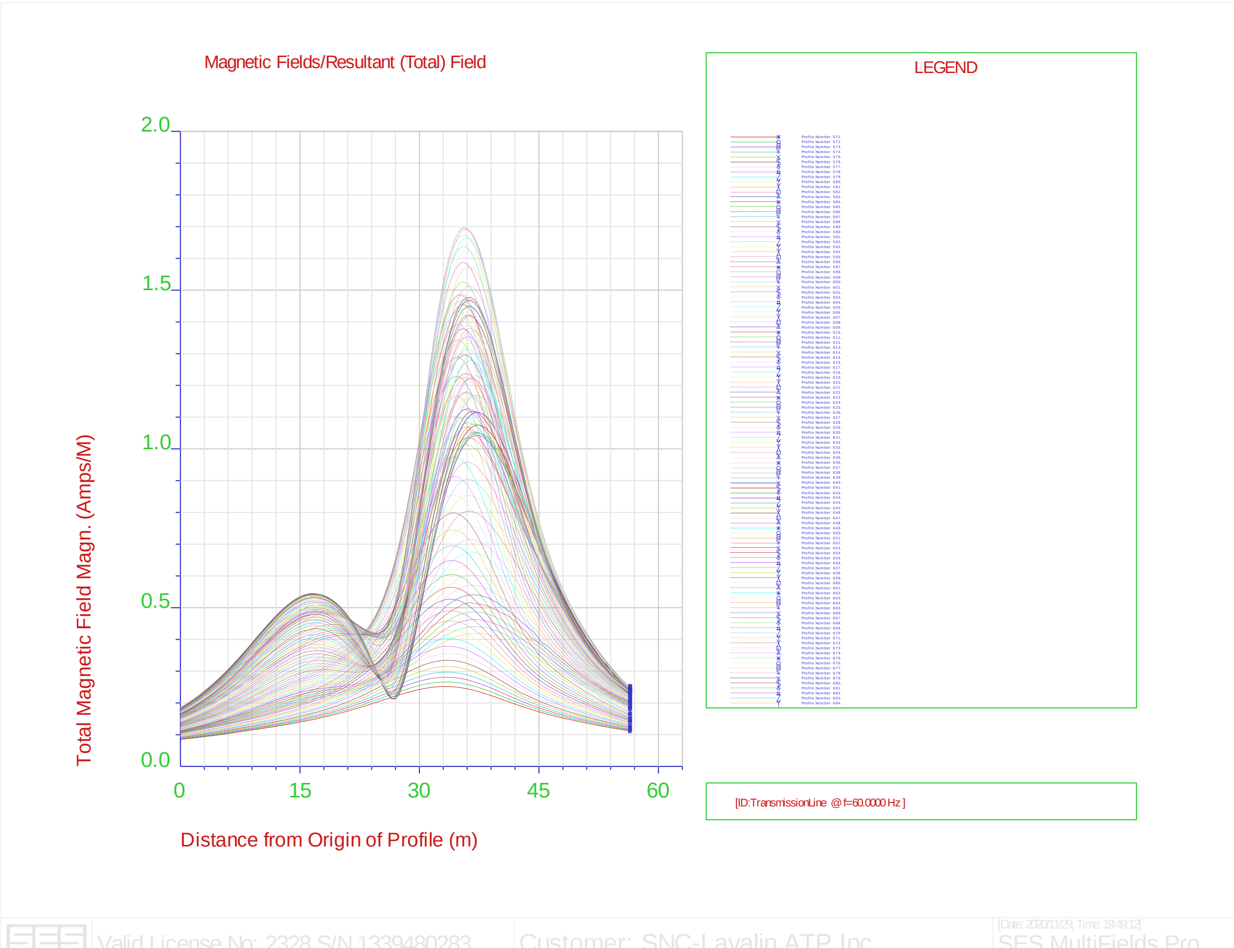

Figure 4-163 2D Magnetic Field Result of OSS2-1200 MW Case at Roof Deck Level

4.2.1.2 HVDC Offshore Substation

As shown in Figures 4-164 and 4-165, the OSS receives the generated power by WTGs through 66 kV AC inter-array cables. Those 66 kV inter-array cables are aggregated by a 66 kV Gas-insulated Switchgear. Then, the voltage is converted by transformers to 380 kV. At this voltage, the electricity is carried from a 400 kV Gas-insulated Switchgear and converted into DC through AC/DC converters at either 320 kV or 525 kV. Then two HVDC offshore export cables carry the electricity to an onshore substation. The simulated OSS included incoming 66 kV inter-array cables, 66 kV Gas-insulated Switchgear, 66 kV/380 kV transformers, 400 kV Gas-insulated Switchgear, and outgoing HVDC offshore export cables. Magnetic fields are calculated at sea level and the six decks for the HVDC OSS.

Figure 4-163 2D Magnetic Field Result of OSS2-1200 MW Case at Roof Deck Level

4.2.1.2 HVDC Offshore Substation

As shown in Figures 4-164 and 4-165, the OSS receives the generated power by WTGs through 66 kV AC inter-array cables. Those 66 kV inter-array cables are aggregated by a 66 kV Gas-insulated Switchgear. Then, the voltage is converted by transformers to 380 kV. At this voltage, the electricity is carried from a 400 kV Gas-insulated Switchgear and converted into DC through AC/DC converters at either 320 kV or 525 kV. Then two HVDC offshore export cables carry the electricity to an onshore substation. The simulated OSS included incoming 66 kV inter-array cables, 66 kV Gas-insulated Switchgear, 66 kV/380 kV transformers, 400 kV Gas-insulated Switchgear, and outgoing HVDC offshore export cables. Magnetic fields are calculated at sea level and the six decks for the HVDC OSS.

One case has been simulated for the HVDC OSS:

- Case 3 (OSS 3 - 1200 MW HVDC): the plant generation rating for this case is 1200 MW. The OSS includes eighteen 66 kV inter-array cables, 66 kV Gas-insulated Switchgear, two 66 kV/380 kV transformers, 400 kV Gas-insulated Switchgear, and two 320 kV or 525 kV HVDC export cables.

The results are presented in Table 4-2. The graphical results are presented in Section 4.2.1.2.1.

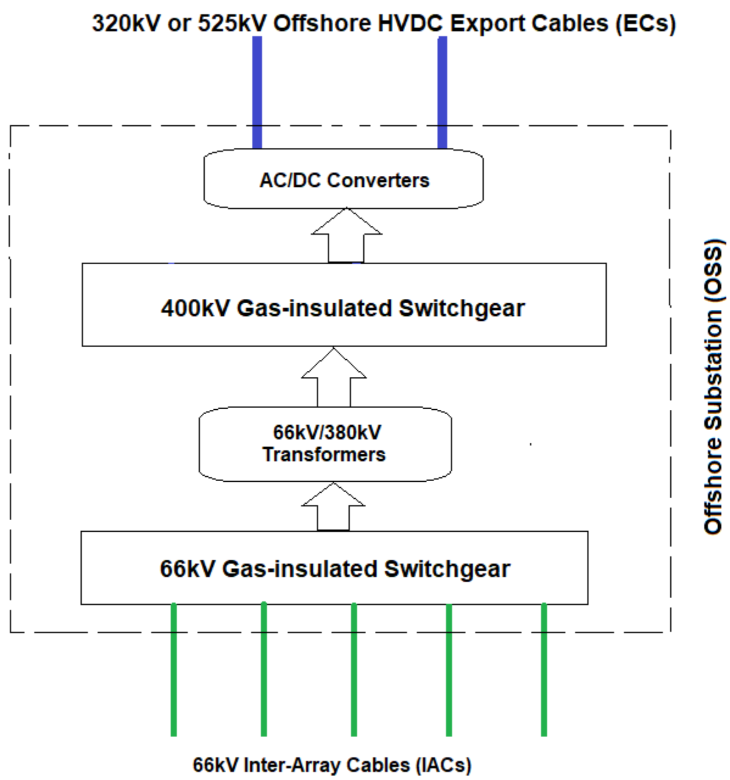

Figure 4-164 Sample Configuration for HVDC Offshore Substations with AC/DC Cables

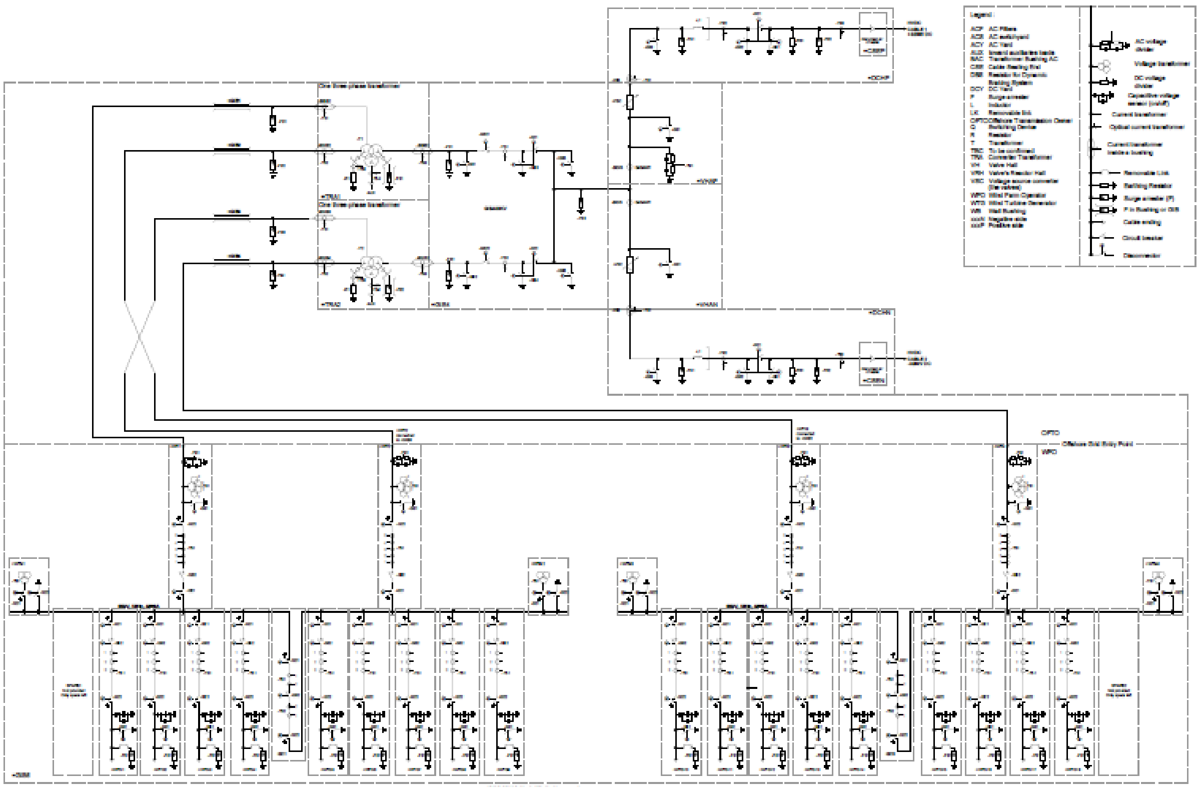

Figure 4-165 Single Line Diagram for HVDC Offshore Substation

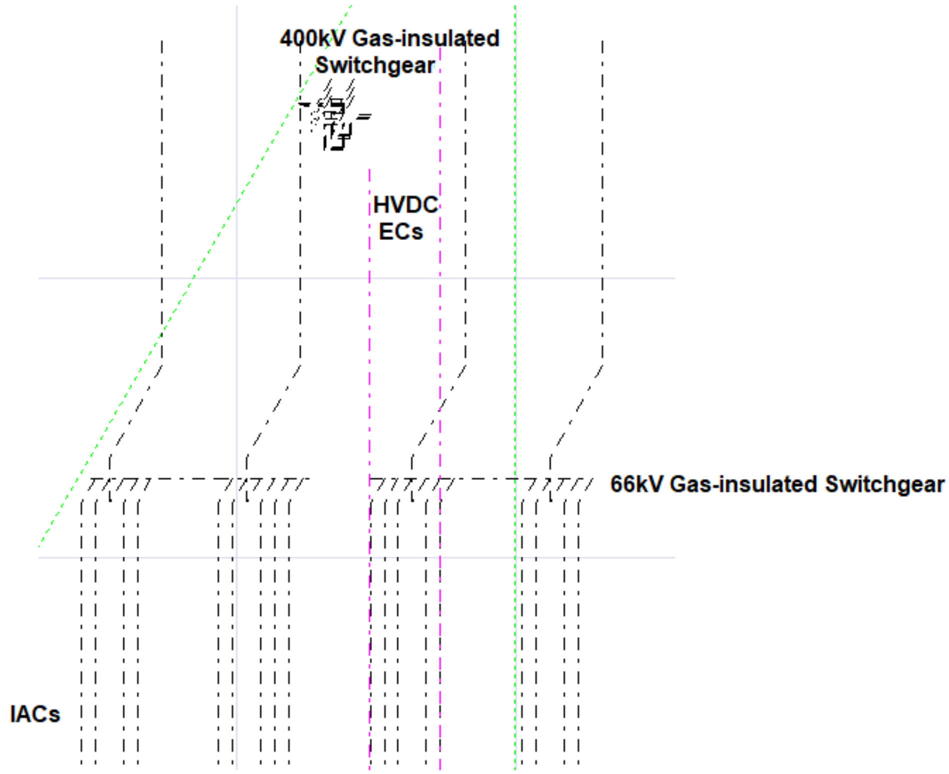

Figure 4-166 OSS3-1200 MW HVDC OSS CDEGS Model

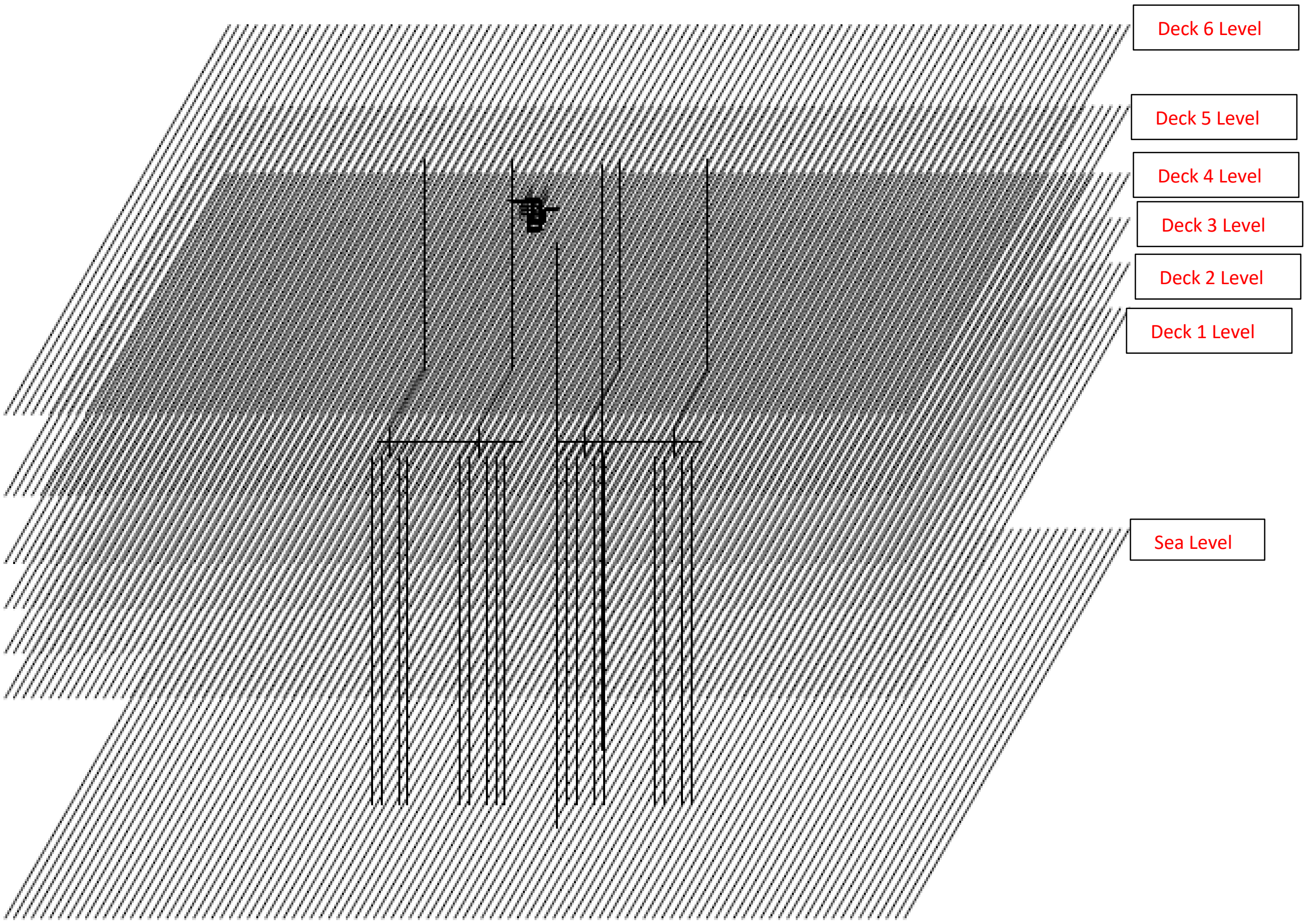

Figure 4-167 OSS3-1200 MW HVDC OSS CDEGS Model with Deck Profiles

Table 4-2 Results Summary for Case 3(OSS3-1200 MW HVDC)

Location of Calculation	Peak Magnetic Field (A/m) for Case 3(OSS3-1200 MW HVDC)	Distance from energized conductor at which magnetic field drops below limits [7]
Sea Level	2770.45	2 feet (0.6 m) from IACs 8.2 feet (2.5m) from HVDC ECs
Deck 1 Level	1097.38	2 feet (0.6 m) from IACs
Deck 2 Level	1660.33	2 feet (0.6 m) from 66 kV Gas-insulated Switchgear bus
Deck 3 Level	1413.32	2 feet (0.6 m) from 66 kV Gas-insulated Switchgear bus
Deck 4 Level	1421.91	2 feet (0.6 m) from 66 kV Gas-insulated Switchgear bus
Deck 5 Level	1421.78	2 feet (0.6 m) from 66 kV Gas-insulated Switchgear bus
Deck 6 Level	764.14	-

It is important to mention that the peak magnetic field violates (160 A/m and 800 A/m) maximum allowable public and occupational limits at sea level and all decks respectively (refer to Table 1-2). However, those peaks occur right at the cables or Gas-insulated Switchgear buses only and the magnetic field decays quickly while moving away from the energized conductor. SNC Lavalin analyzed the magnetic field profiles to determine the distance from the energized conductor at which the magnetic field value fall below the respective limits. The results of this analysis are indicated in Table 4-2.

The magnetic field in other areas is within maximum allowable limit (refer to Figures 4-168, 4-170, 4-172, 4-174, 4-176, and 4-178). The magnetic field at Deck 6 is within its 800 A/m maximum occupational allowable limit.

Comparing calculated magnetic fields with the 160 A/m maximum allowable limit for general public is not of concern as it is anticipated that the OSS decks will be accessed only by trained workers. The magnetic fields at the sea level can be compared with 160 A/m limit as the OSS can be approached at sea level by general public. It can be seen that at the locations other than right at the cables at sea level, the magnetic fields are lower than 160 A/m.

[7] Refer to Appendix A

4.2.1.2.1 Results for Case 3 (OSS3-1200 MW HVDC)

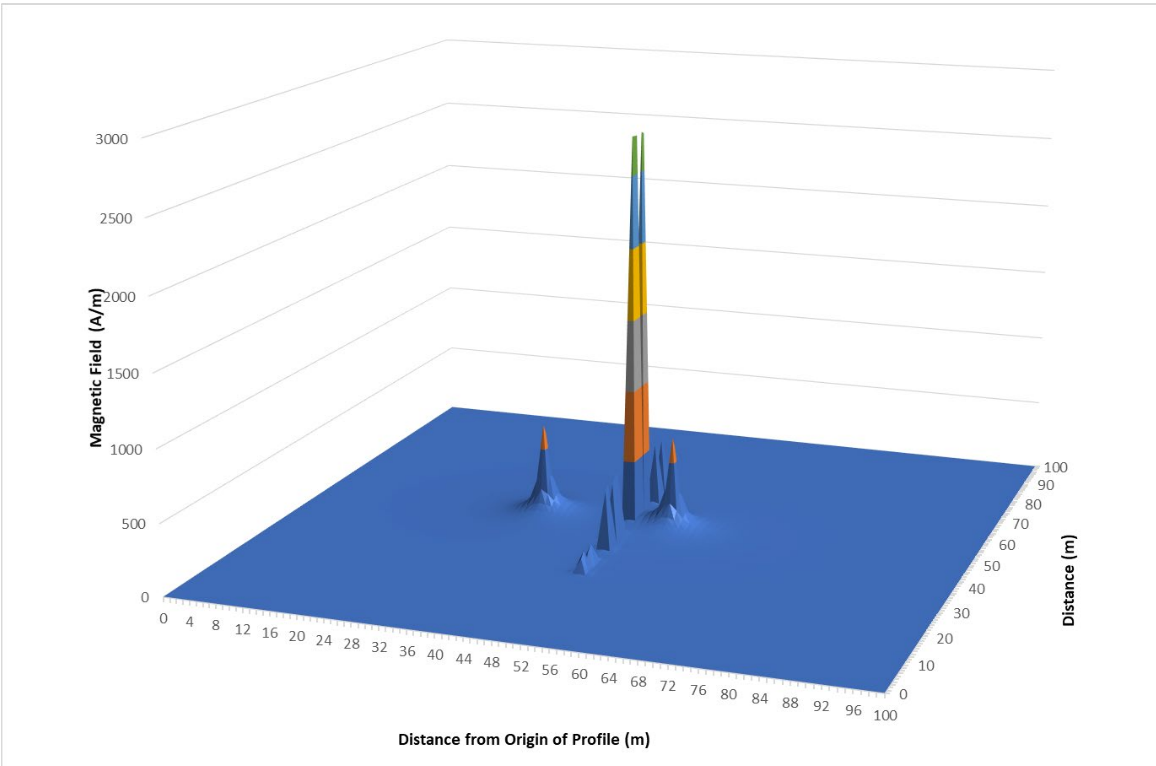

Figure 4-168 3D Magnetic Field Result of OSS3-1200 MW HVDC Case at sea level

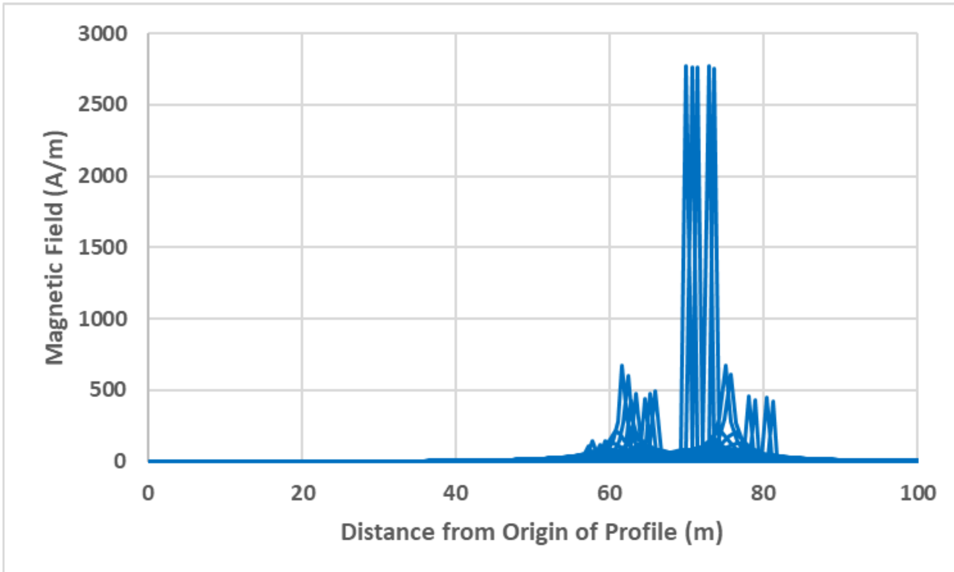

Figure 4-169 2D Magnetic Field Result of OSS3-1200 MW HVDC Case at sea level

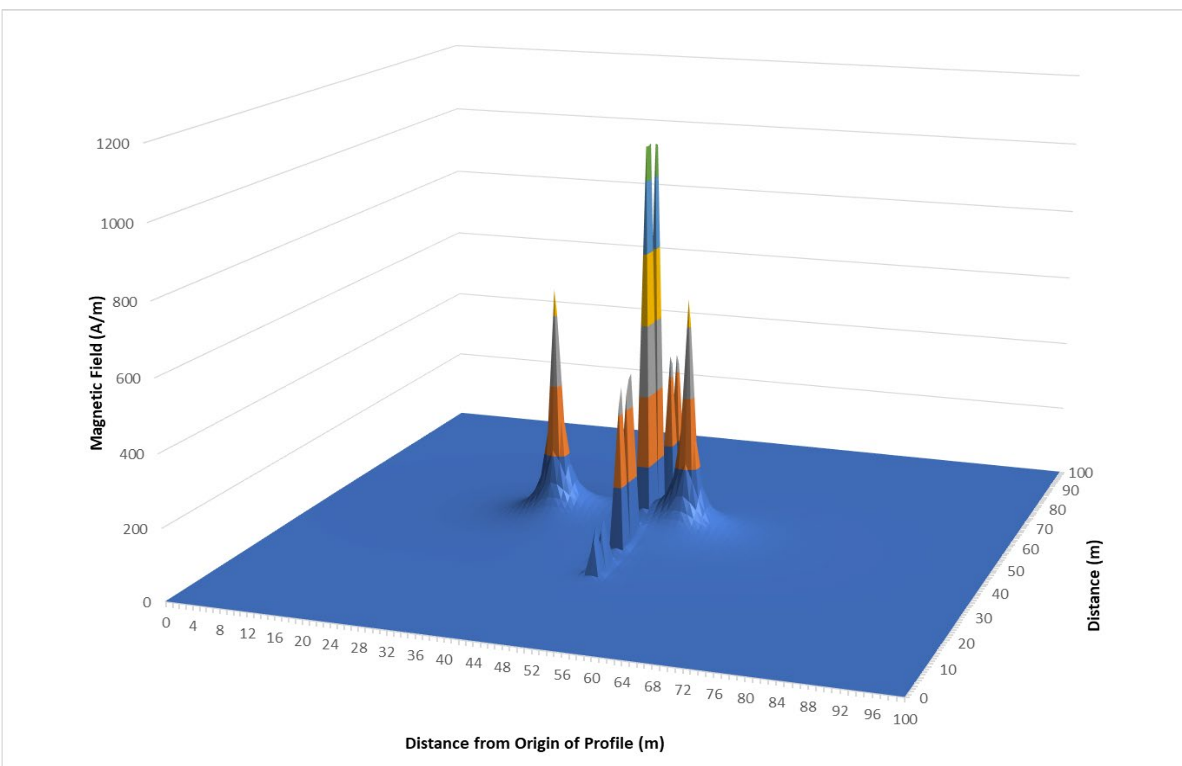

Figure 4-170 3D Magnetic Field Result of OSS3-1200 MW HVDC Case at Deck 1 Level

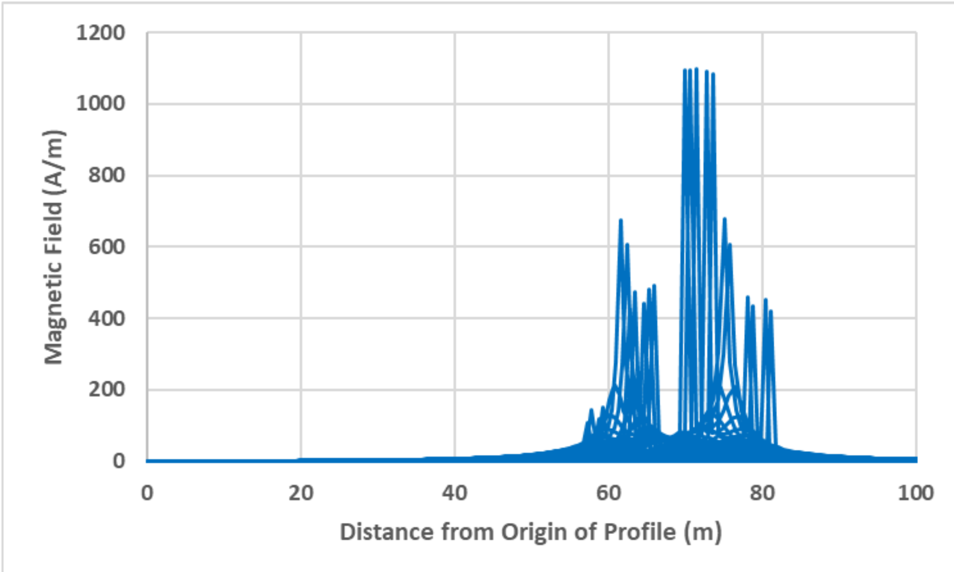

Figure 4-171 2D Magnetic Field Result of OSS3-1200 MW HVDC Case at Deck 1 Level

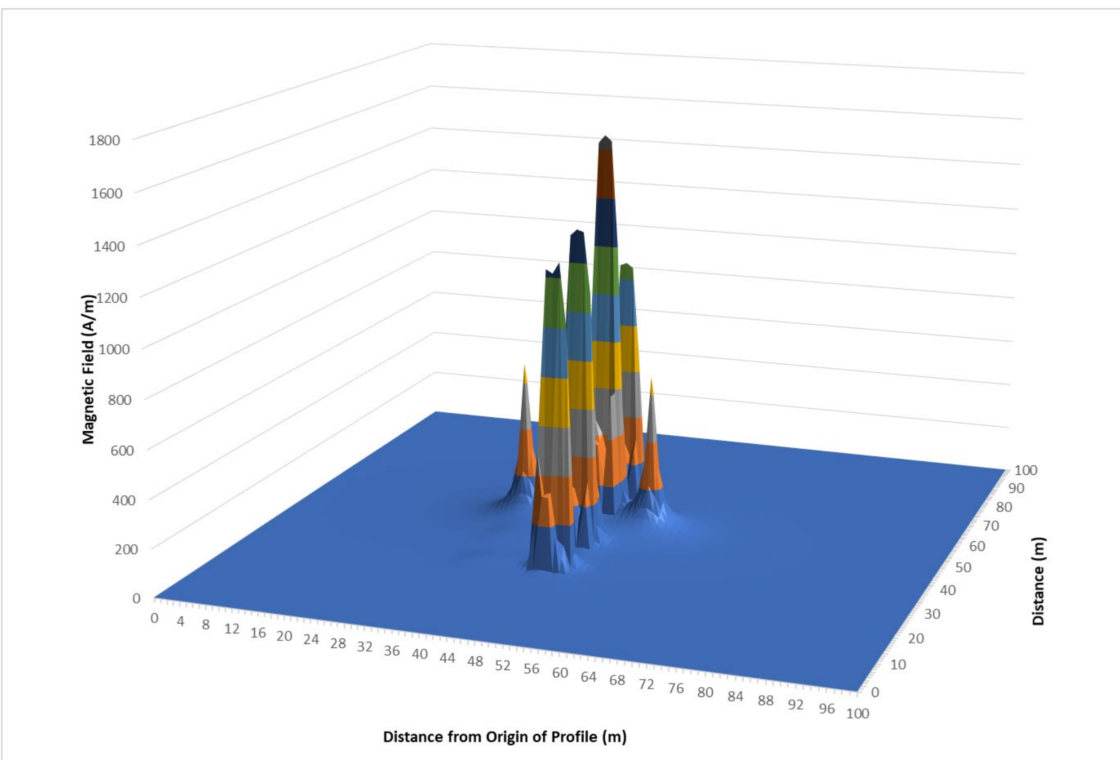

Figure 4-172 3D Magnetic Field Result of OSS3-1200 MW HVDC Case at Deck 2 Level

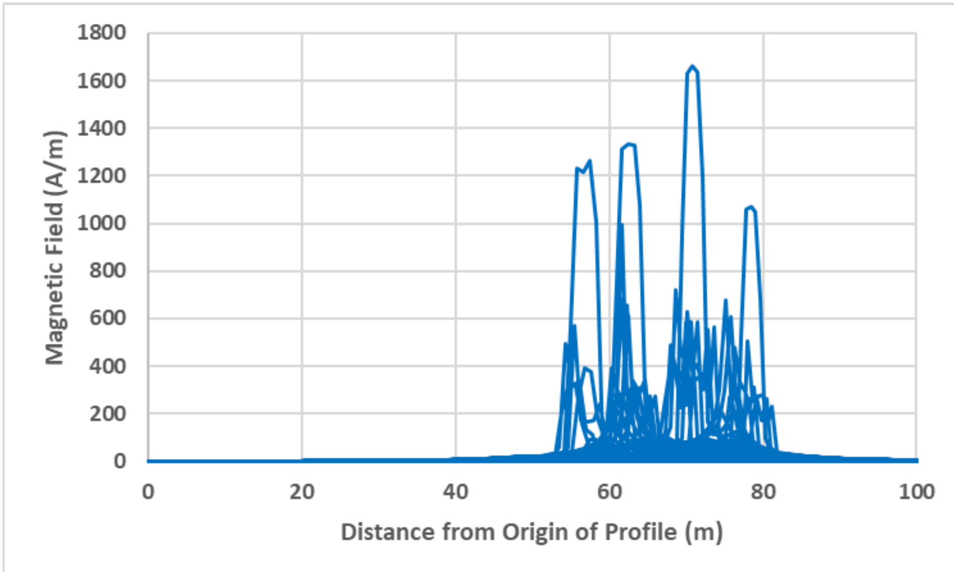

Figure 4-173 2D Magnetic Field Result of OSS3-1200 MW HVDC Case at Deck 2 Level

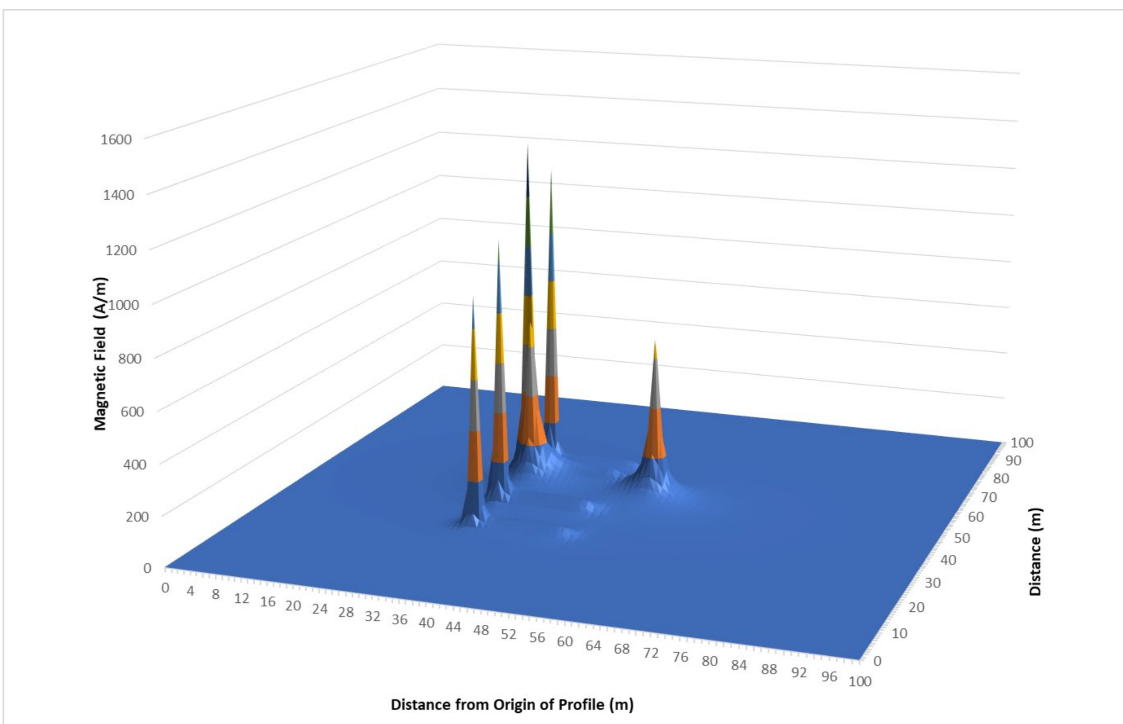

Figure 4-174 3D Magnetic Field Result of OSS3-1200 MW HVDC Case at Deck 3 Level

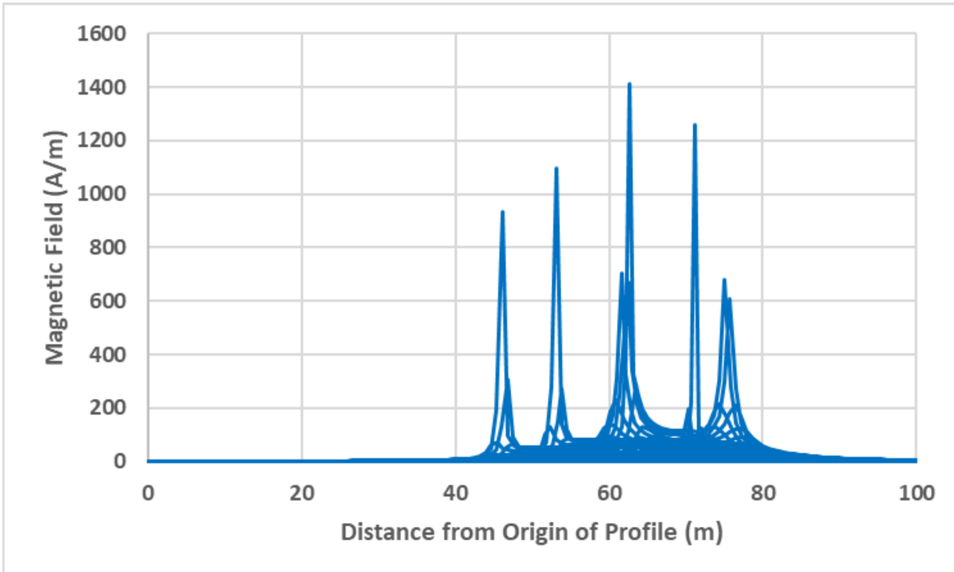

Figure 4-175 2D Magnetic Field Result of OSS3-1200 MW HVDC Case at Deck 3 Level

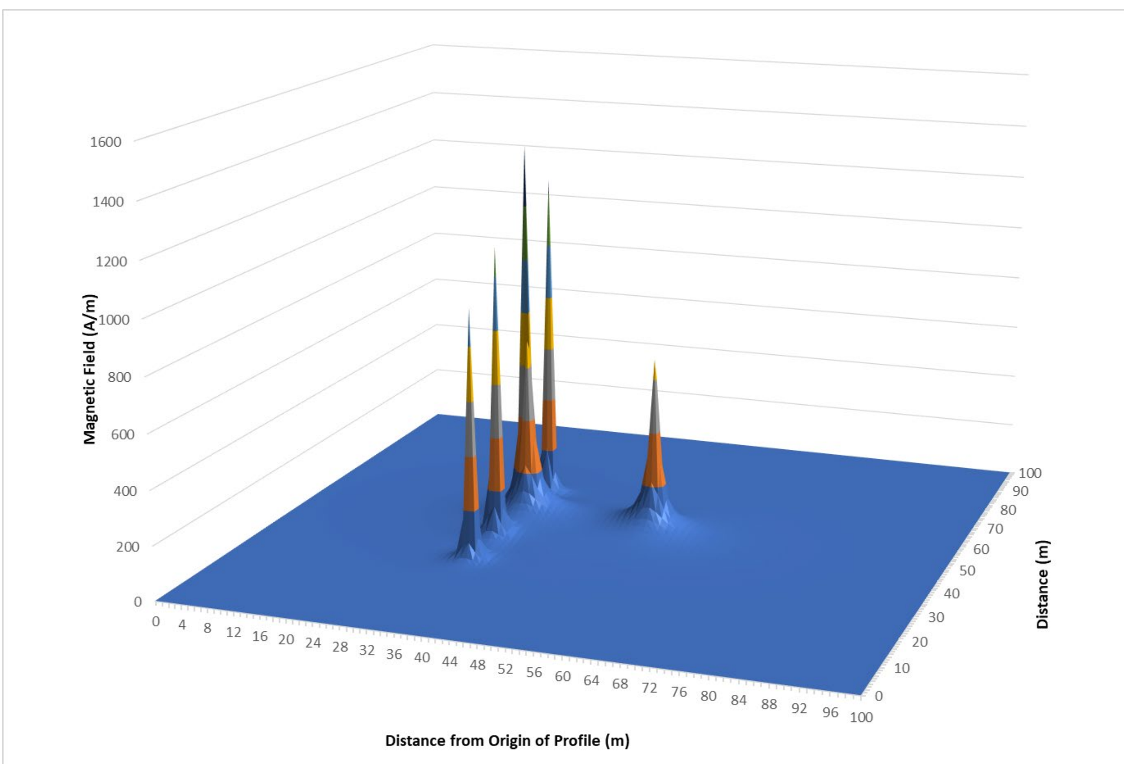

Figure 4-176 3D Magnetic Field Result of OSS3-1200 MW HVDC Case at Deck 4 Level

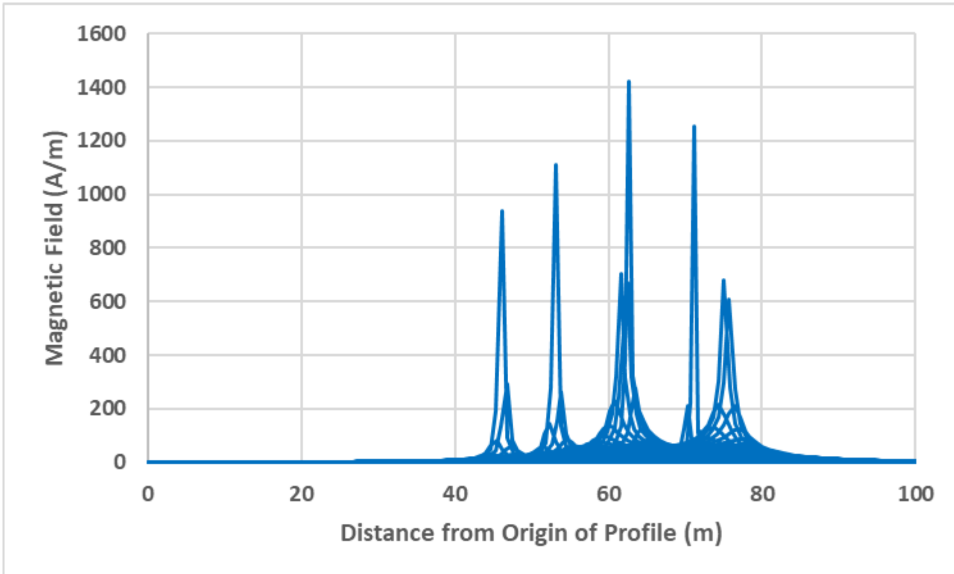

Figure 4-177 2D Magnetic Field Result of OSS3-1200 MW HVDC Case at Deck 4 Level

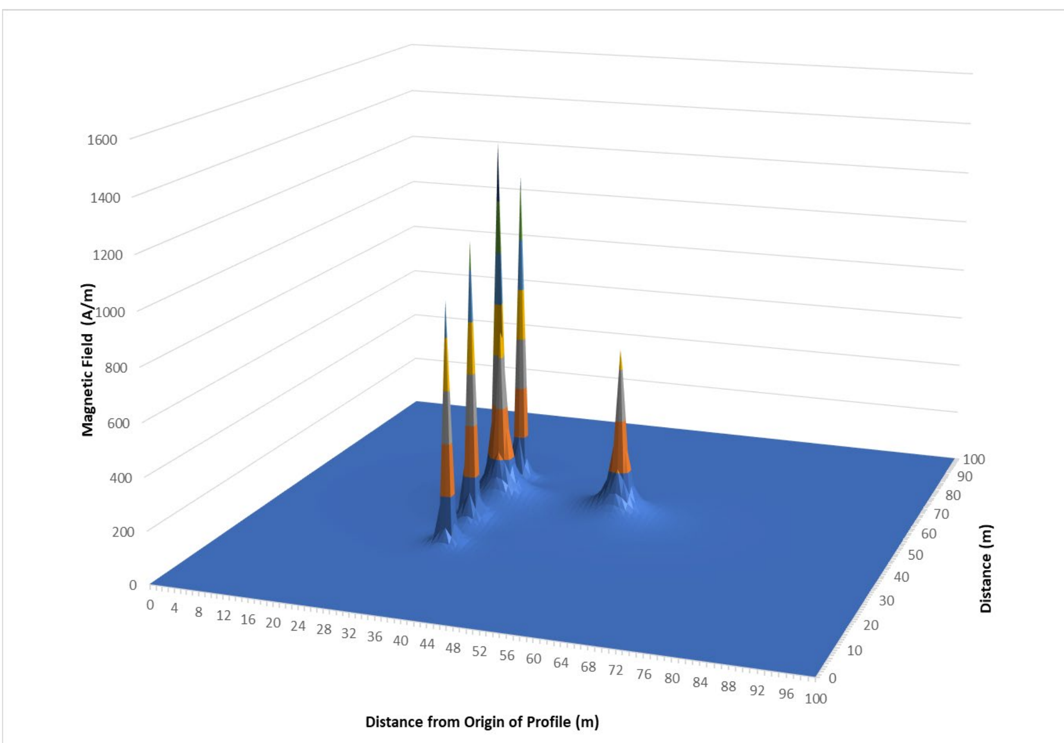

Figure 4-178 3D Magnetic Field Result of OSS3-1200 MW HVDC Case at Deck 5 Level

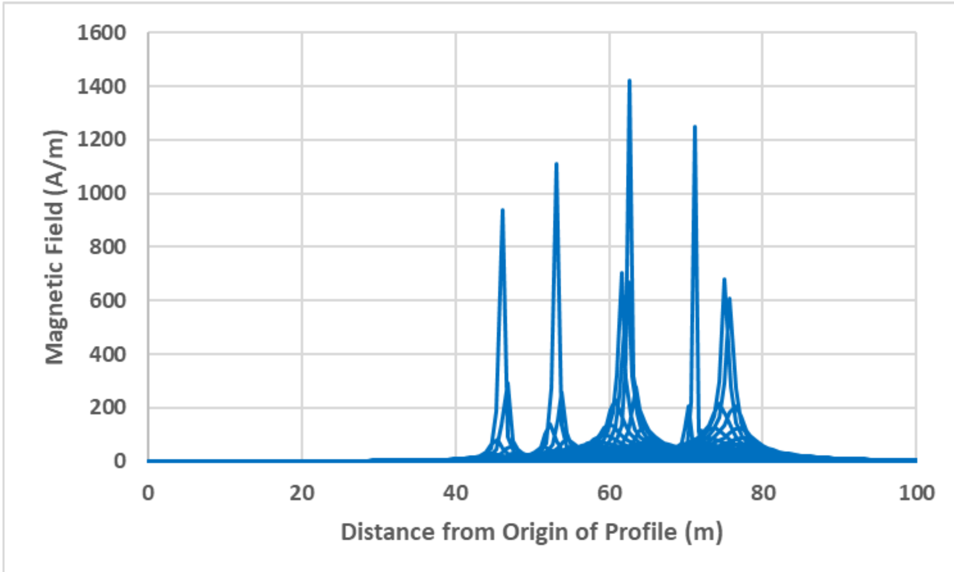

Figure 4-179 2D Magnetic Field Result of OSS3-1200 MW HVDC Case at Deck 5 Level

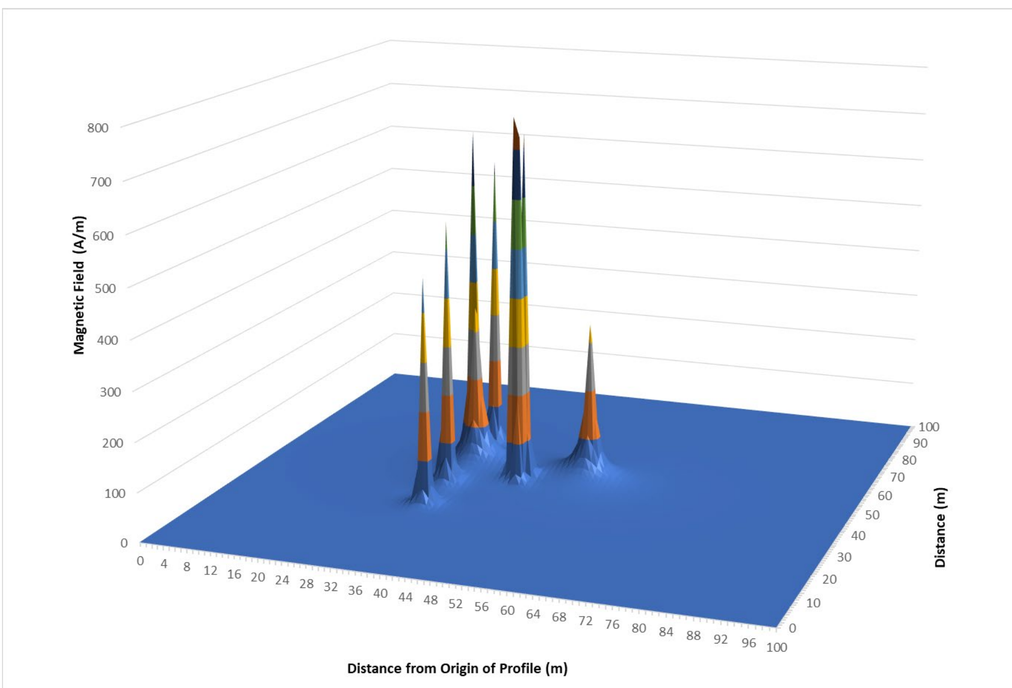

Figure 4-180 3D Magnetic Field Result of OSS3-1200 MW HVDC Case at Deck 6 Level

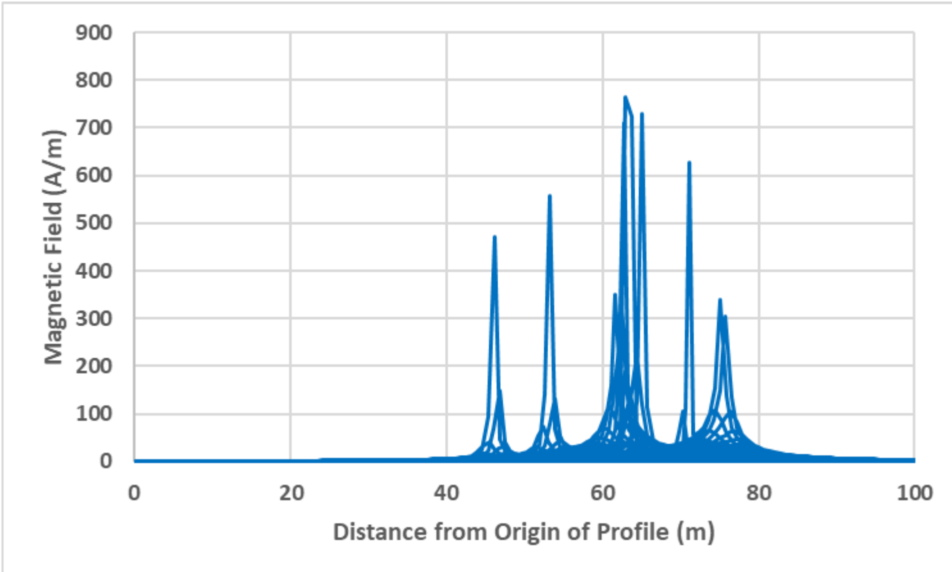

Figure 4-181 2D Magnetic Field Result of OSS3-1200 MW HVDC Case at Deck 6 Level

4.2.2 Onshore Substation (Case 4: Onshore Substation 230/230 kV or 275/230 kV)

This section presents the results for Cardiff 1200 MW 230/230 kV and Larrabee 1200 MW 275/230 kV onshore substations (refer to Figure 4-182). At the onshore substation, voltage will be converted to 230 kV to be carried to the local transmission electrical grid POI Substation.

Figures 4-184 and 4-185 show the magnetic field within onshore substation. The peak magnetic field is 72.76 A/m. Thus, this peak magnetic field is within its 800 A/m maximum occupational allowable limit and 160 A/m maximum allowable limit for general public.

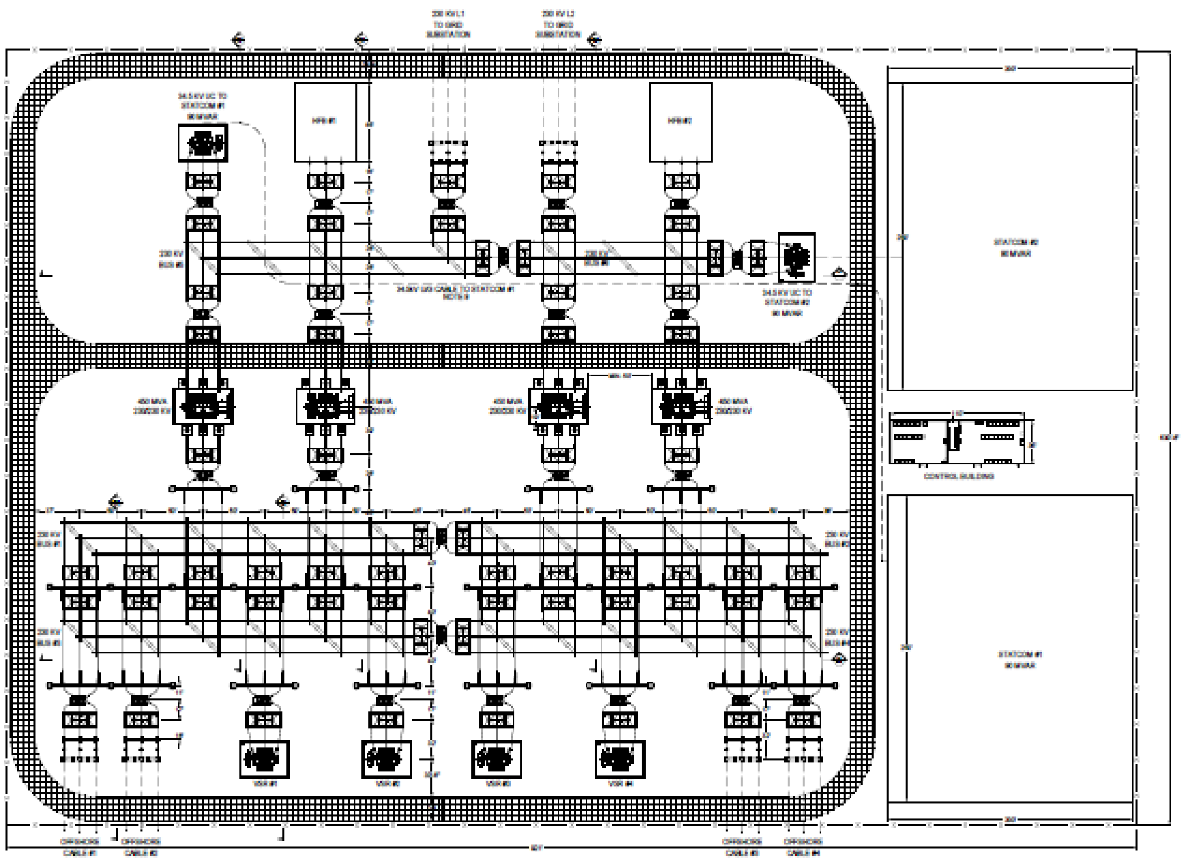

Figure 4-182 Onshore Substation Layout

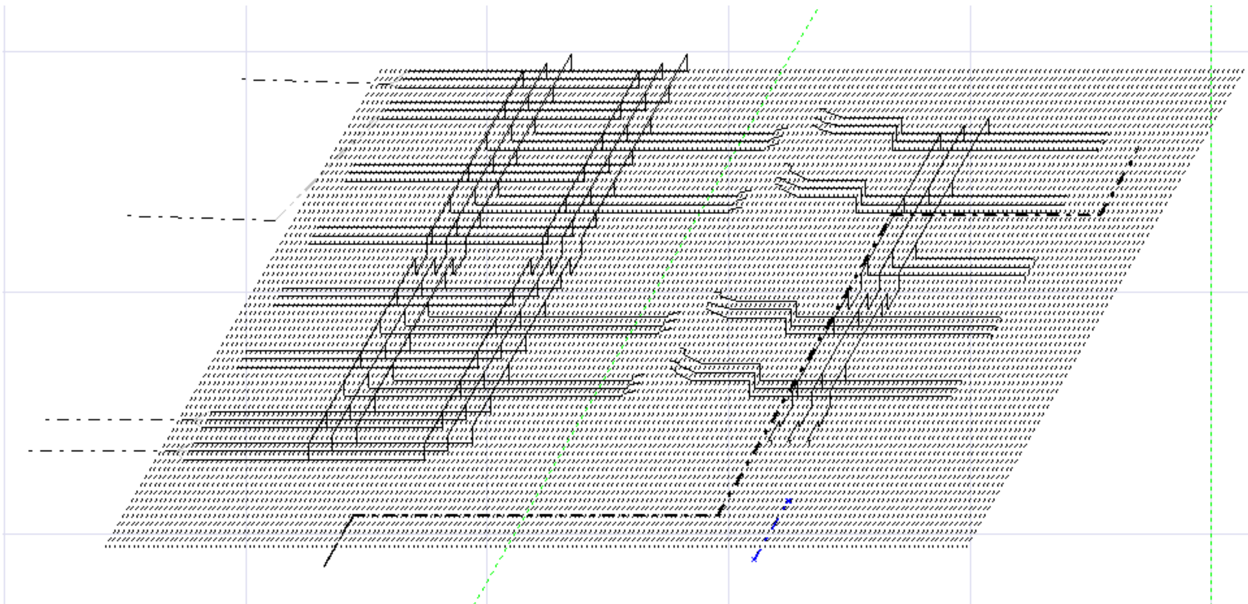

Figure 4-183 Onshore Substation CDEGS Model

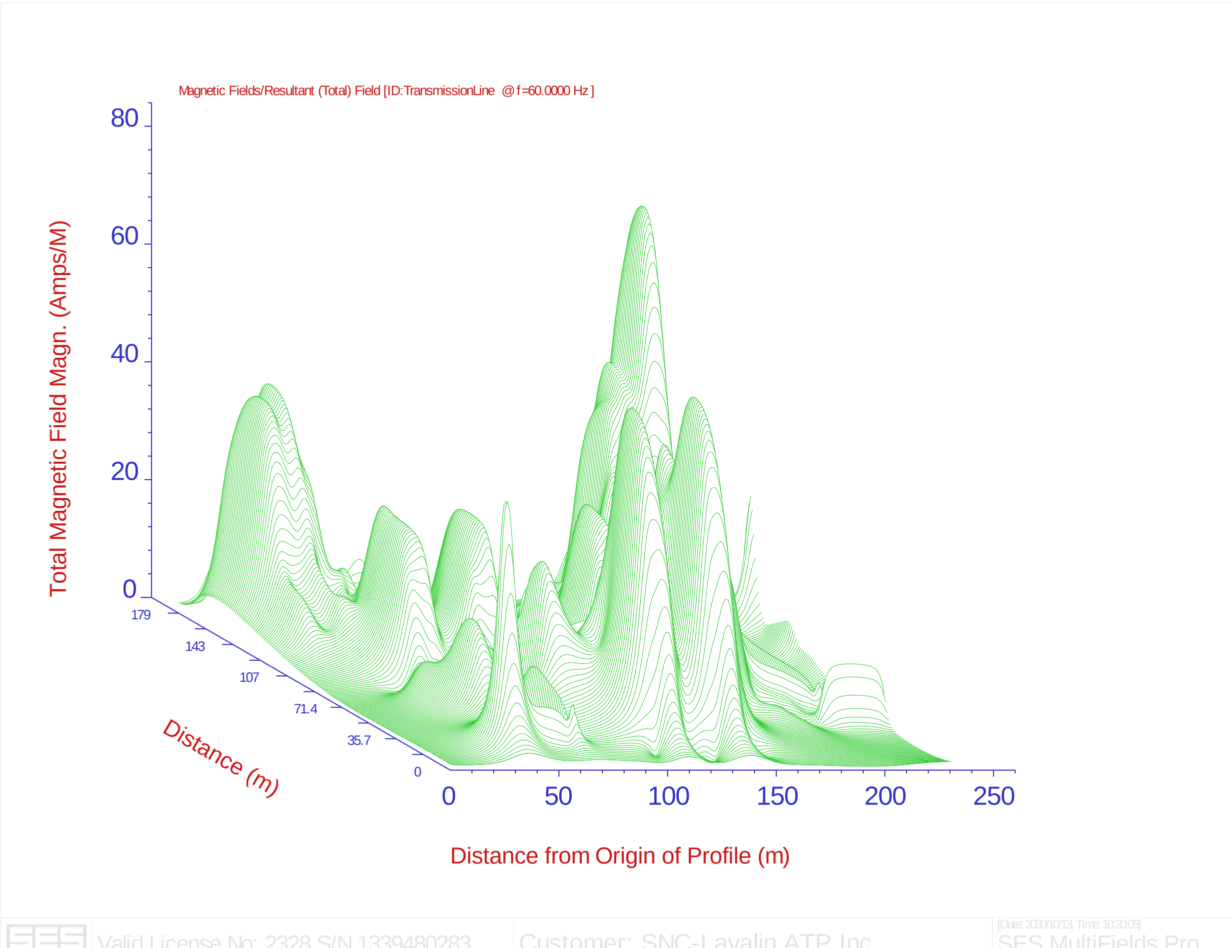

Figure 4-184 3D Magnetic Field Result of Onshore Substation

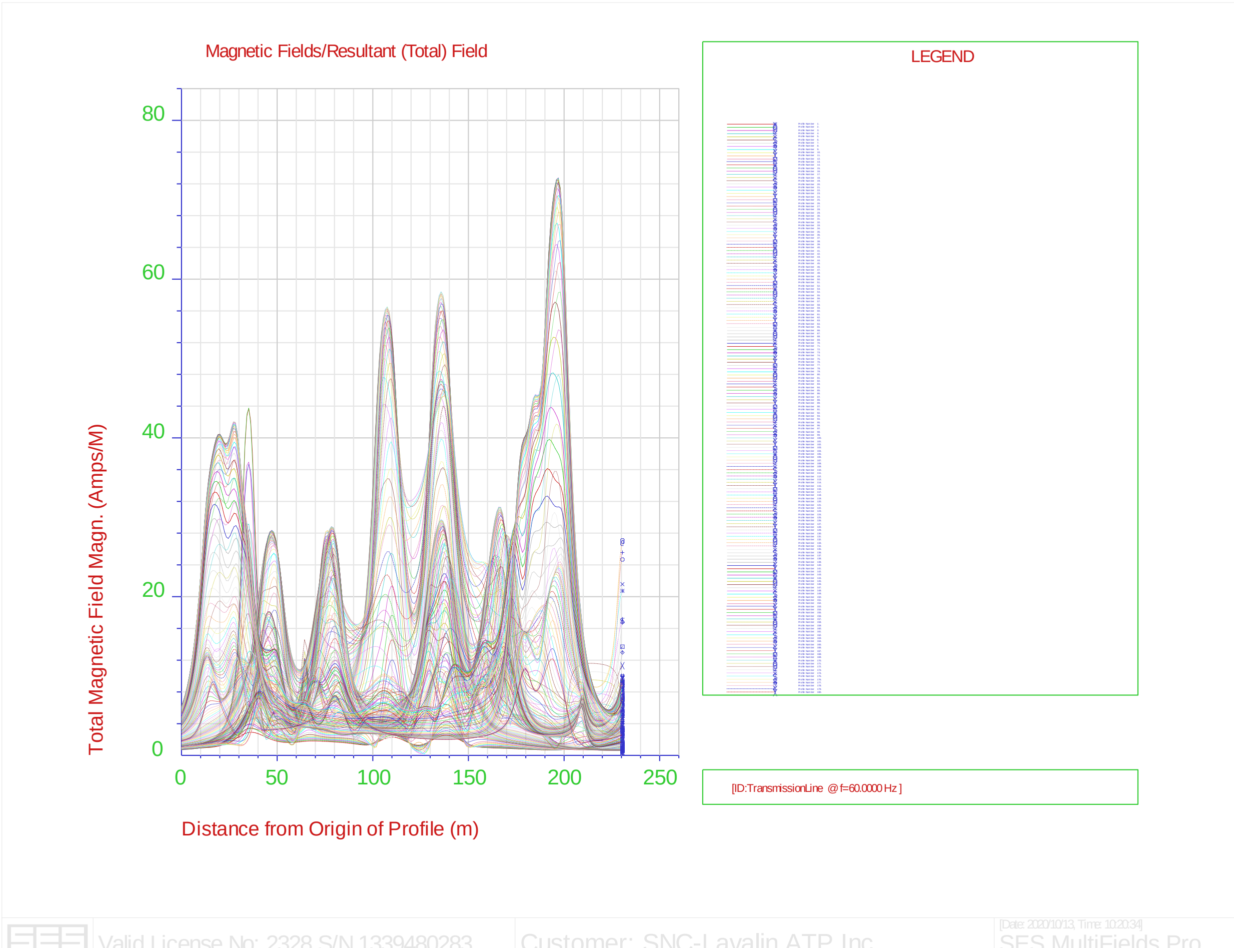

Figure 4-185 2D Magnetic Field Result of Onshore Substation

4.3 Electric Field Results

The electric field from the offshore export cables, inter-array cables and Gas-insulated switchgear bus ducts is blocked by the grounded cable armoring and duct enclosures as well as the earth and will not be a direct source of any electric field outside the cables or bus ducts. Therefore, this section represents the electric field results only for the onshore substation Case and Case number 47 (in
Table **3-5**) which pertains to the overhead line section between the onshore substation and POI substation.

4.3.1 Onshore Substation (Case 4: OnSS 230/230 kV or 275/230 kV)

Figures 4-186 to 4-189 show the electric field within 230/230 kV or 275/230 kV onshore substations. It was assumed that the OnSS is operating at a voltage 10% higher than the nominal operating voltage. The peak electric field is 10.58 kV/m and 13.49 kV/m for 230/230 kV and 275/230 kV onshore substations. The peak electric field inside the station fence violates the 8.333 kV/m maximum allowable occupational limit (refer to Table 1-2). Outside the station fence the electric fields are below the 4.167 kV/m general public limit (refer to Table 1-2). Since electric field is inversely proportional to the distance of measurement location from the energized object, increasing the bus heights of the OnSS can be used to mitigate higher electric fields.

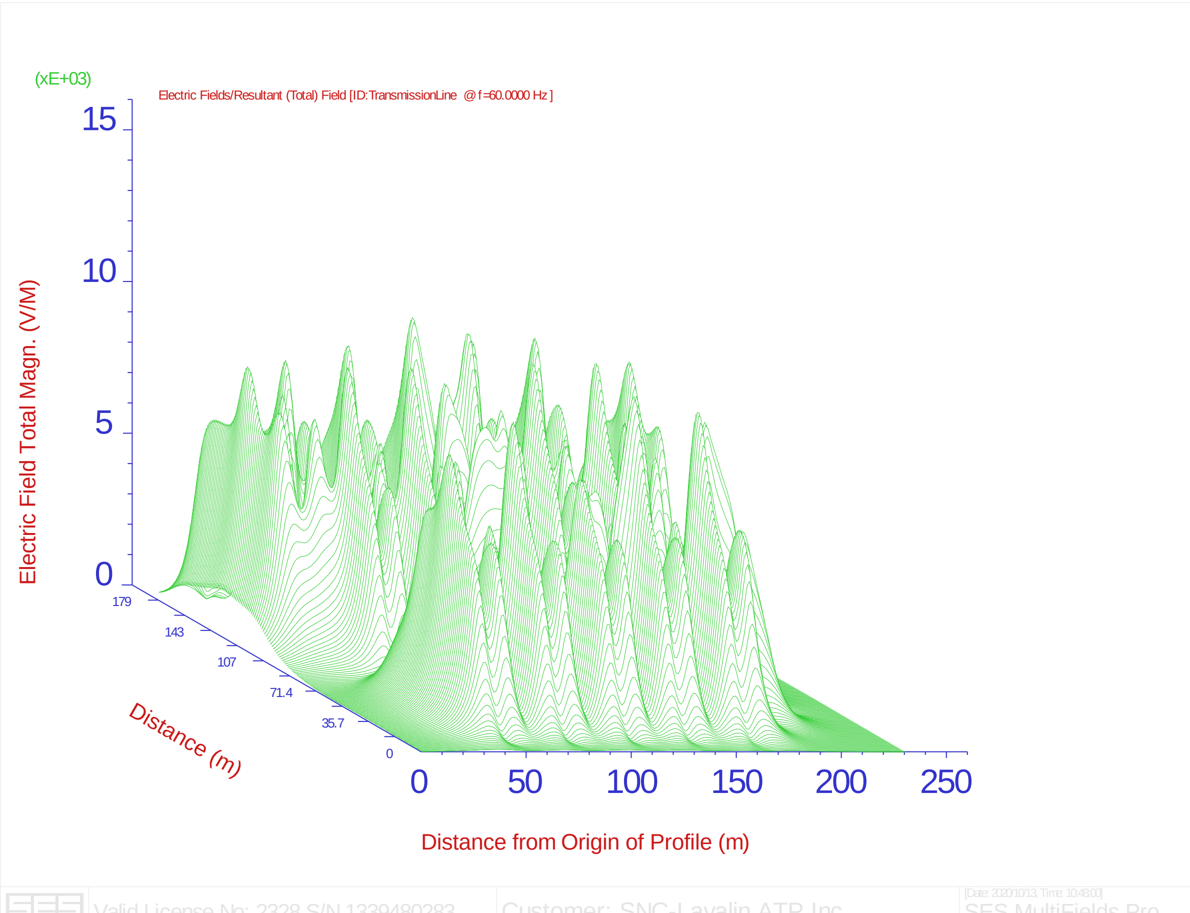

Figure 4-186 3D Electric Field Result of 230/230 kV Onshore Substation

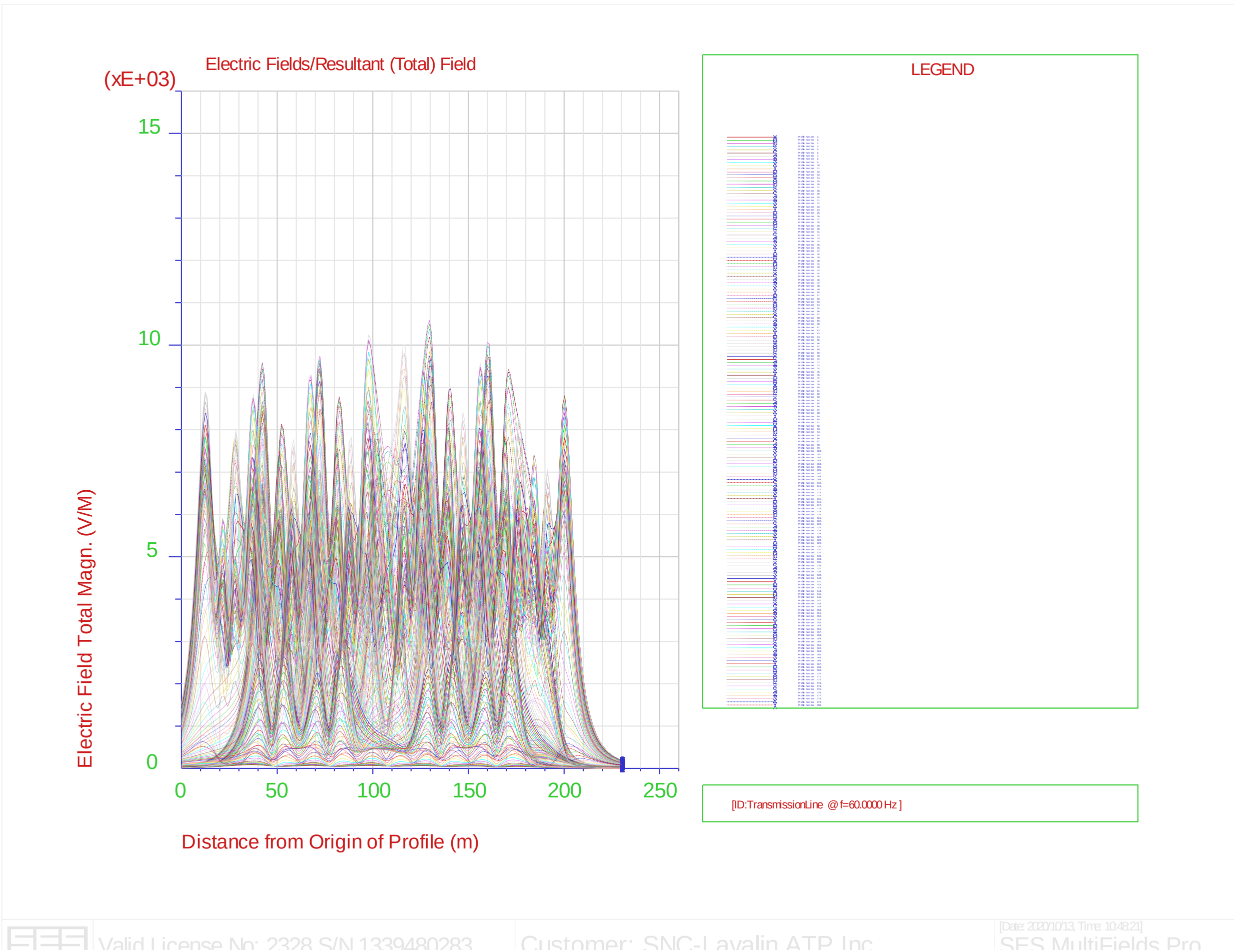

Figure 4-187 2D Electric Field Result of 230/230 kV Onshore Substation

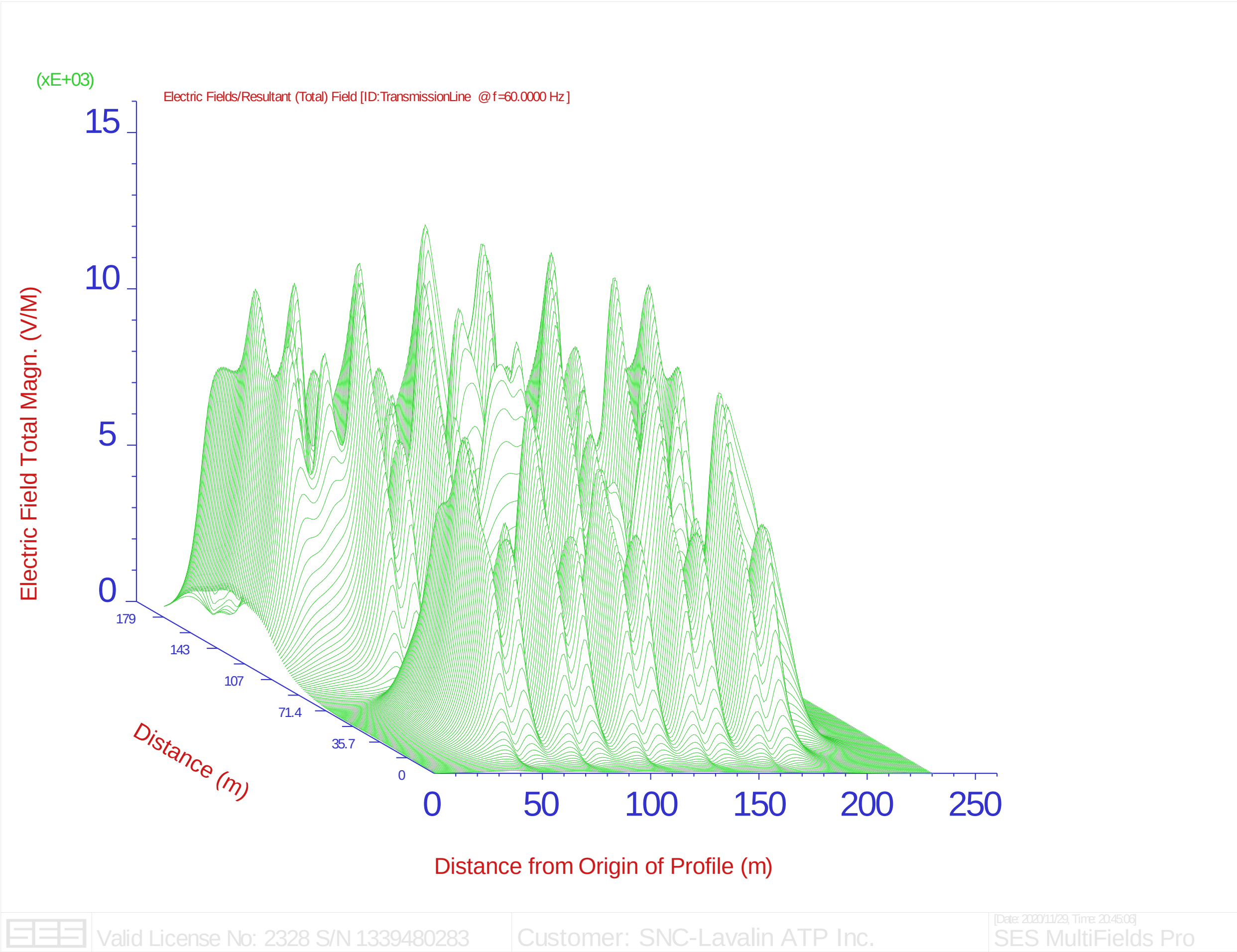

Figure 4-188 3D Electric Field Result of 275/230 kV Onshore Substation

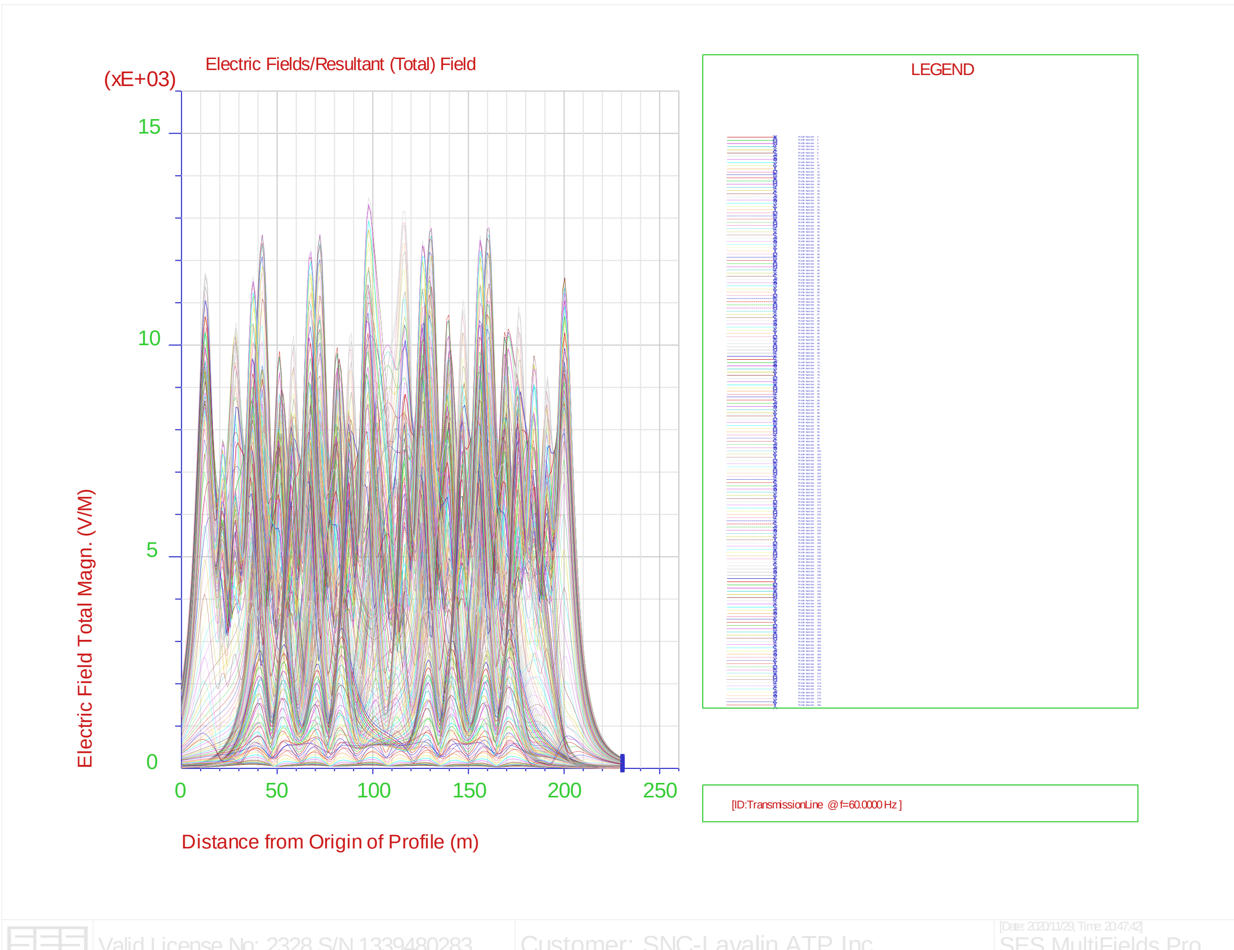

Figure 4-189 2D Electric Field Result of 275/230 kV Onshore Substation

4.3.2 Case 47 230 kV Overhead line from Onshore Substation to POI

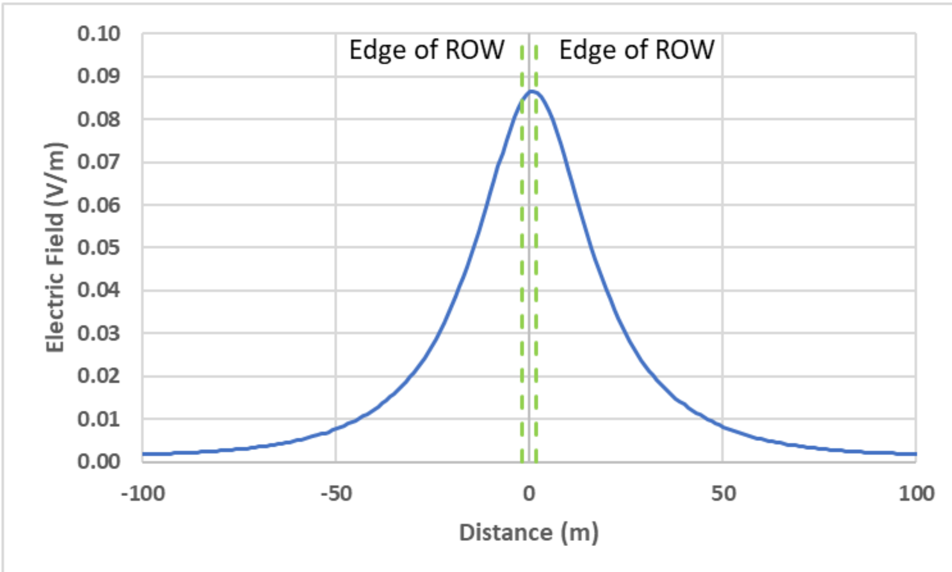

Figure 4-190 Electric Field Result of Case 47

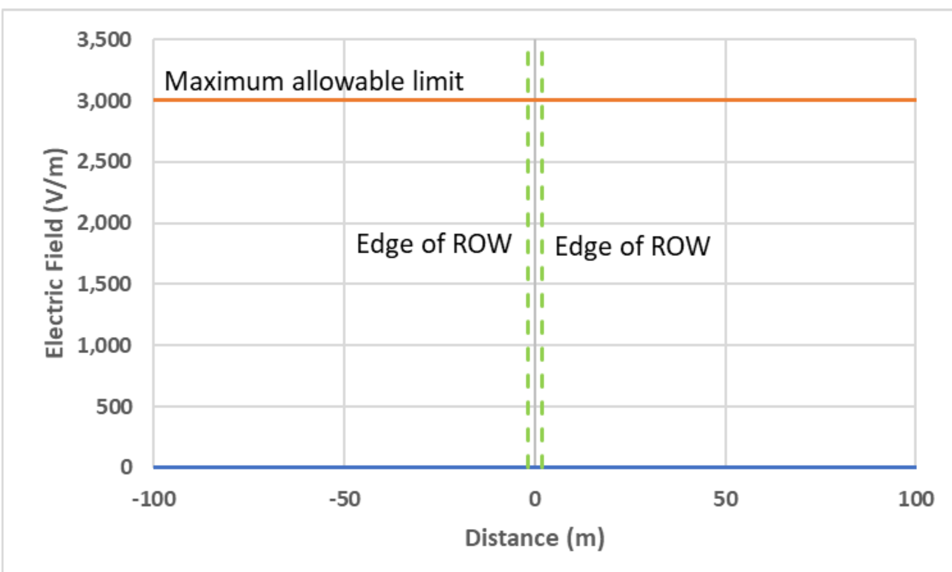

Figure 4-191 Electric Field Result of Case 47 with Maximum Limit

As shown in Figures 4-190 to 4-191, the peak electric field for case 47 is 0.087 V/m which is lower than the 3 kV/m maximum allowable limit.

5 Discussion & Conclusions

The Project circuit maps and overall single line diagrams provided by Atlantic Shores show the following main electrical system components:

1. Inter-array cables
2. OSS
3. Offshore export cables and onshore interconnection transmission cables
4. Onshore substation

Study Cases were developed for each project component listed above. The Cases developed were modelled using CDEGS ver.16.2 considering the electrical installation details of different feeder arrangements to evaluate the EMF strengths. The primary conclusions are discussed in subsections a-d below.

a) **Cable Cases (Cases 1-52)**

Table 5-1 presents the magnetic field results obtained for cable Cases 1-52 and compares them with the maximum allowable limits. From the comparison, it can be concluded that the magnetic field is within its maximum allowable limits for all cases throughout the ROW.

The electric field from the shielded power cables (Cases 1-52 with the exception of Case 47) is not included as it is blocked by the grounded cable armoring as well as the earth. Electric field from cables will not be a direct source of any electric field outside the cables. The peak electric field for Case 47 is 0.087 V/m which is lower than the 3 kV/m maximum allowable limit.

Table 5-1 Summary Results for Cable Cases

Case no.	Magnetic Field				Case no.	Magnetic Field			
	Result		Allowable limit			Result		Allowable limit	
	A/m	mG	A/m	mG		A/m	mG	A/m	mG
1	3.84	48.25	160	2010.62	30	8.00	100.53	160	2010.62
2	1.68	21.11	160	2010.62	31	1.05	13.19	160	2010.62
3	4.55	57.18	160	2010.62	32	8.25	103.67	160	2010.62
4	1.99	25.01	160	2010.62	33	18.87	237.13	160	2010.62
5	4.78	60.07	160	2010.62	34	19.45	244.42	160	2010.62
6	2.08	26.14	160	2010.62	35	18.44	231.72	160	2010.62
7	8.45	106.19	160	2010.62	36	19.03	239.14	160	2010.62
8	8.71	109.45	160	2010.62	37	3.35	42.10	400	5026.55
9	8.40	105.56	160	2010.62	38	12.15	152.68	400	5026.55
10	8.66	108.82	160	2010.62	39	27.79	349.22	400	5026.55
11	8.40	105.56	160	2010.62	40	93.24	1171.69	400	5026.55
12	8.66	108.82	160	2010.62	41	173.04	2174.48	400	5026.55
13	8.36	105.05	160	2010.62	42	263.03	3305.33	400	5026.55
14	8.62	108.32	160	2010.62	43	16.85	211.74	160	2010.62
15	8.34	104.80	160	2010.62	44	19.27	242.15	160	2010.62
16	8.61	108.20	160	2010.62	45	15.74	197.79	160	2010.62
17	8.32	104.55	160	2010.62	46	18.57	233.36	160	2010.62
18	8.58	107.82	160	2010.62	47	12.41	155.95	160	2010.62
19	14.52	182.46	160	2010.62	48	48.00	603.19	400	5026.55
20	146.53	1841.35	160	2010.62	49	0.76	9.55	400	5026.55
21	14.34	180.20	160	2010.62	49-1	18.60	233.73	400	5026.55
22	146.66	1842.98	160	2010.62	49-2	3.77	47.38	400	5026.55
23	14.66	184.22	160	2010.62	49-3	80.27	1008.70	400	5026.55
24	146.34	1838.96	160	2010.62	50	93.77	1178.35	400	5026.55
25	1.03	12.94	160	2010.62	51	5.21	65.47	400	5026.55
26	8.33	104.68	160	2010.62	51-1	59.77	751.09	400	5026.55
27	1.07	13.45	160	2010.62	51-2	32.18	404.39	400	5026.55
28	8.58	107.82	160	2010.62	52	48.01	603.31	400	5026.55
29	1.02	12.82	160	2010.62					

b) HVAC Offshore Substation Case (Cases 1 and 2)

Table 5-2 presents the results obtained for magnetic fields. From the summarized results in Table 5-2, it can be concluded that:

- The magnetic field violates its (160 A/m (2010.62 mG) and 800 A/m (10053.10 mG)) maximum allowable public and occupational limits at sea level and main deck level respectively (refer to Table 1-2). However, those peaks occur right at the cables or Gas-insulated Switchgear buses only and the magnetic field decays quickly while moving away from the energized conductor. SNC Lavalin calculated the distance from the energized conductor at which the magnetic field value fall below the respective limits.

- The magnetic field at other Levels (Cellar Deck, Cable Deck, Utility Deck, Roof Deck) is within its 800 A/m (10053.10 mG) maximum occupational allowable limit.

- Comparing calculated magnetic fields with the 160 A/m (2010.62 mG) maximum allowable limit for general public is not of concern as it is anticipated that the OSS decks will be accessed only by trained workers. The magnetic fields at the sea level can be compared with 160 A/m (2010.62 mG) limit as the OSS can be approached at sea level by general public. It can be seen that at the locations other than right at the cables at sea level, the magnetic fields are lower than 160 A/m (2010.62 mG).
- Electric field from Gas-insulated Switchgear bus enclosure will not be a direct source of any electric field outside the grounded enclosure.

Table 5-2 Summary Results for Offshore HVAC Substation

Location of Calculation	Peak Magnetic Field for Case 1(OSS1-800 MW)		Peak Magnetic Field for Case 2(OSS2-1200 MW)		Distance from energized conductor at which magnetic field drops below limits	
	A/m	mG	A/m	mG	OSS1 (800 MW)	OSS2 (1200 MW)
Sea Level	1000.46	12572.15	971.56	12208.98	1.31 feet (0.4 m) from ECs 1 feet (0.3 m) from IACs	1 feet (0.3 m) from ECs 1 feet (0.3 m) from IACs
Cellar Deck Level	480.79	6041.79	389.68	4896.86	-	-
Cable Deck Level	649.66	8163.87	389.18	4890.58	-	-
Main Deck Level	990.82	12451.01	1181.50	14847.17	1 feet (0.3 m) from 230 kV or 275 kV Gas-insulated Switchgear bus	1.31 feet (0.4 m) from 230 kV or 275 kV Gas-insulated Switchgear bus
Utility Deck Level	116.89	1468.88	136.31	1712.92	-	-
Roof Deck Level	6.83	85.83	1.70	21.36	-	-

c) HVDC Offshore Substation Case (Case 3)

Table 5-3 presents the results obtained for magnetic fields. From the summarized results in Table 5-3, it can be concluded that:

- The magnetic field violates (160 A/m (2010.62 mG) and 800 A/m (10053.10 mG)) maximum allowable public and occupational limits at sea level and all decks respectively (refer to Table 1-2). However, those peaks occur right at the cables or Gas-insulated Switchgear buses only and the magnetic field decays quickly while moving away from the energized conductor. SNC Lavalin calculated the distance from the energized conductor at which the magnetic field value fall below the respective limits.

- The magnetic field at Deck 6 is within its 800 A/m (10053.10 mG) maximum allowable occupational limit.
- Comparing calculated magnetic fields with the 160 A/m (2010.62 mG) maximum allowable limit for general public is not of concern as it is anticipated that the OSS decks will be accessed only by trained workers. The magnetic fields at the sea level can be compared with 160 A/m (2010.62 mG) limit as the OSS can be approached at sea level by general public. It can be seen that at the locations other than right at the cables at sea level, the magnetic fields are lower than 160 A/m (2010.62 mG).
- Electric field from Gas-insulated Switchgear bus enclosure will not be a direct source of any electric field outside the grounded enclosure.

Table 5-3 Summary Results for Offshore HVDC Substation

Location of Calculation	Peak Magnetic Field for Case 3(OSS3-1200 MW HVDC)		Distance from energized conductor at which magnetic field drops below limits
	A/m	mG	
Sea Level	2770.45	34814.50	2 feet (0.6 m) from IACs 8.2 feet (2.5m) from HVDC ECs
Deck 1 Level	1097.38	13790.08	2 feet (0.6 m) from IACs
Deck 2 Level	1660.33	20864.32	2 feet (0.6 m) from 66 kV Gas-insulated Switchgear bus
Deck 3 Level	1413.32	17760.30	2 feet (0.6 m) from 66 kV Gas-insulated Switchgear bus
Deck 4 Level	1421.91	17868.25	2 feet (0.6 m) from 66 kV Gas-insulated Switchgear bus
Deck 5 Level	1421.78	17866.61	2 feet (0.6 m) from 66 kV Gas-insulated Switchgear bus
Deck 6 Level	764.14	9602.47	-

d) Onshore Substation Case (Case 4)

Table 5-4 presents the results obtained for both magnetic and electric fields. From the summarized results in Table 5-4, it can be concluded that:

- The magnetic field is within its 800 A/m (10053.10 mG) maximum allowable occupational limit and 160 A/m (2010.62 mG) maximum allowable limit for general public.
- The peak electric field is 10.58 kV/m for 230/230 kV and 13.49 kV/m for 275/230 kV onshore substations. The peak electric field inside the station fence violates the 8.333 kV/m maximum allowable occupational limit (refer to Table 1-2). Outside the station fence the electric fields are below the 4.167 kV/m general public limit (refer to Table 1-2). Since electric field is inversely proportional to the distance of measurement location from the energized object, increasing the bus heights of the OnSS can be used to mitigate higher electric fields.

Table 5-4 Summary Results for Onshore Substation

Case 4 (OnSS 230/230 kV or 275/230 kV)				
		Magnetic Field		Electric Field (V/m)
		A/m	mG	
Onshore Substation	230/230 kV	72.76	914.33	10583.44
	275/230 kV	72.76	914.33	13493.16

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[16]. 880 MW OSS General Arrangement. Main Deck. Drawing no. A131951-0905-S03-L03 1.

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[32]. Onshore Cable Route – Scenario 1 Details. Drawing no. A131951-1500-S01-L06-1
[33]. Onshore Cable Trenches Standard Outline. Drawing no. A131951-1502-SX-L06-1
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[36]. Onshore Substation Single Line diagram – HV/MV Cardiff. Drawing no. A131951-0700-S01-L02-1
[37]. Onshore Substation Single Line diagram – HV/MV Larrabee. Drawing no. A131951-0700-S02-L02-1
[38]. Onshore Substation Single Line diagram – HV/MV Gowanus. Drawing no. A131951-0700-S03-L02-1
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[56]. Atlantic Offshore Wind Cardiff 1600 MW 230 kV Substation, AIS Switchyard Elevation D-D E-E F-F. Drawing no. 667967.4760.53

APPENDIX A

OSS results with 800A/m threshold at different Deck Levels and 160A/m threshold at sea level.

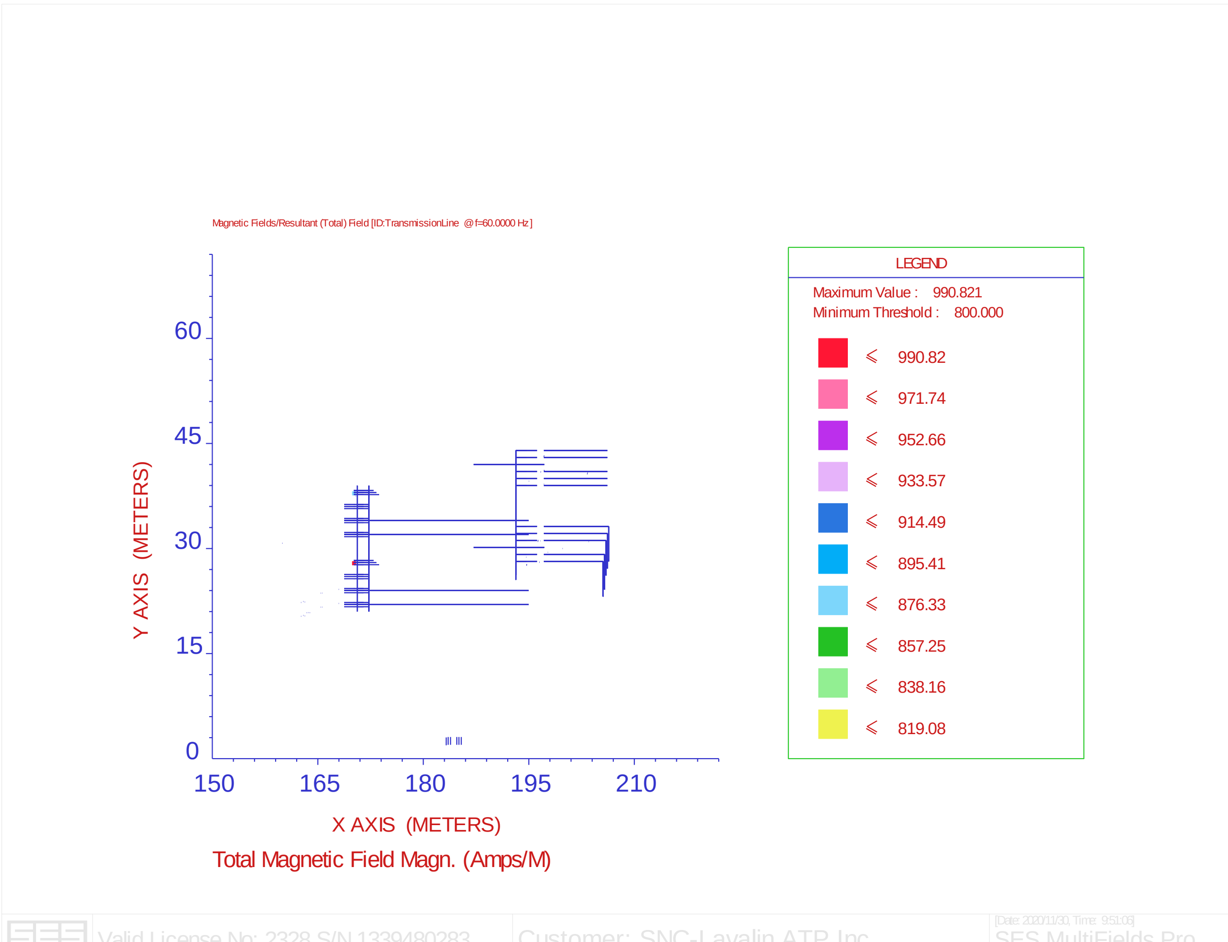

Figure 0-1 Magnetic Field at Main Deck Level for OSS1 (800 MW HVAC)

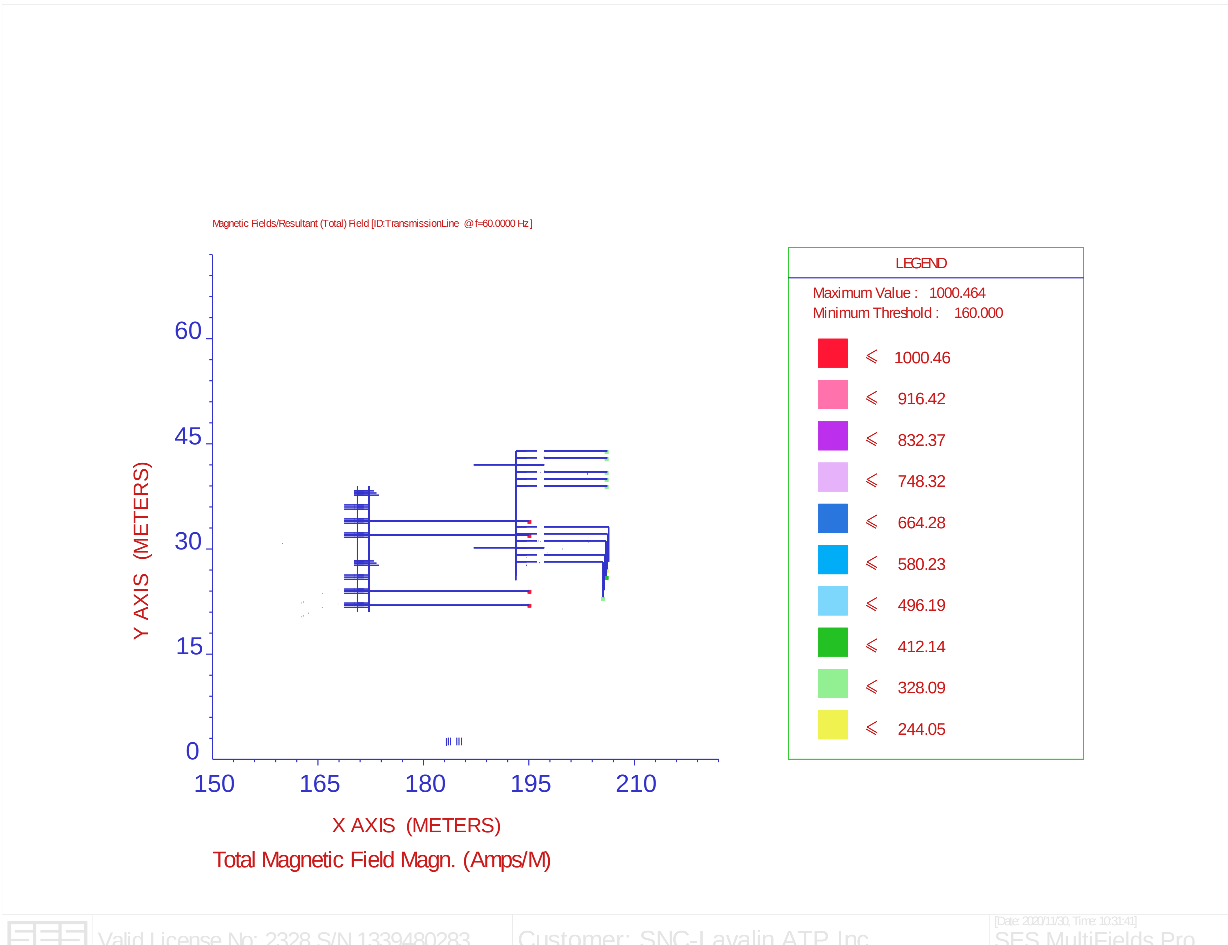

Figure 0-2 Magnetic Field at sea level for OSS1 (800 MW HVAC)

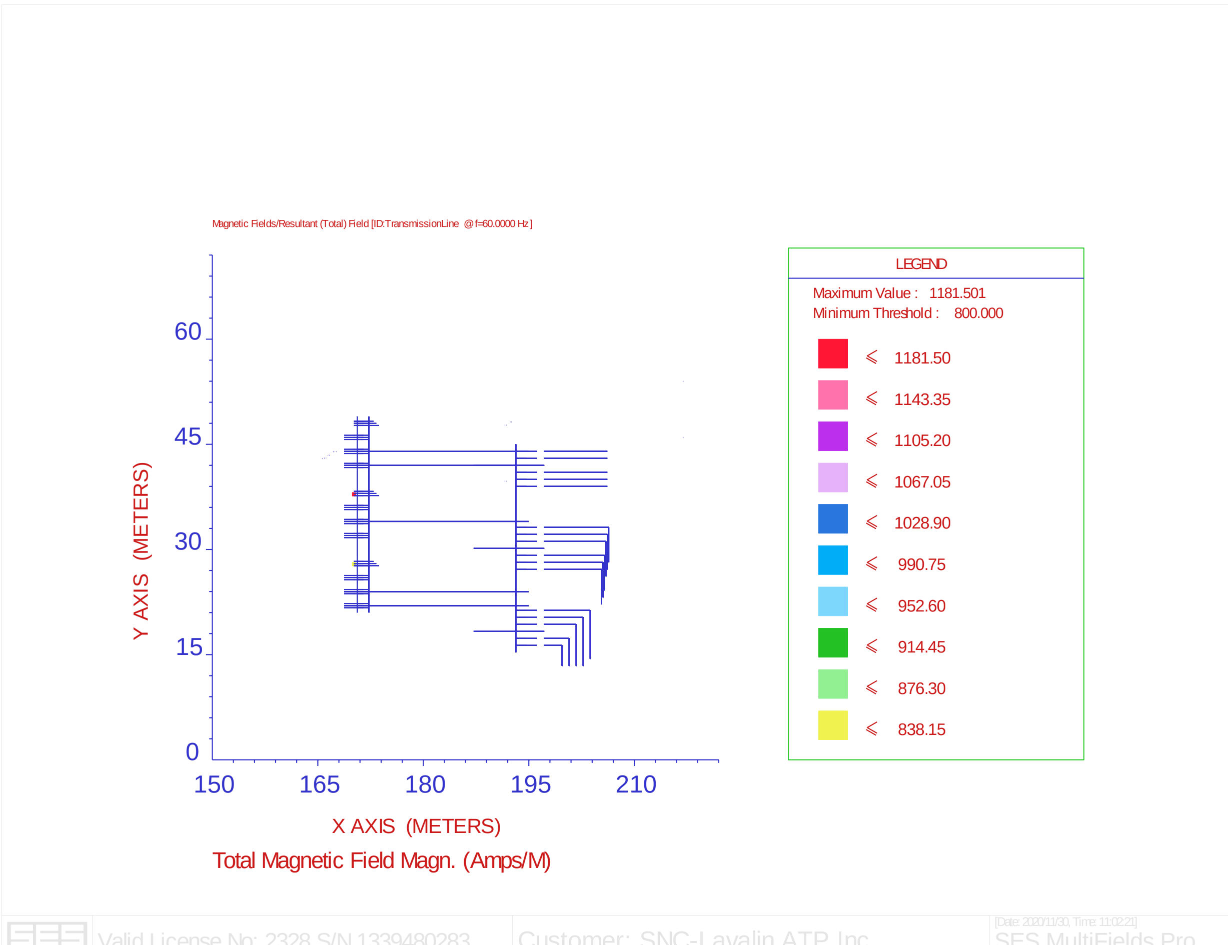

Figure 0-3 Magnetic Field at Main Deck Level for OSS2 (1200 MW HVAC)

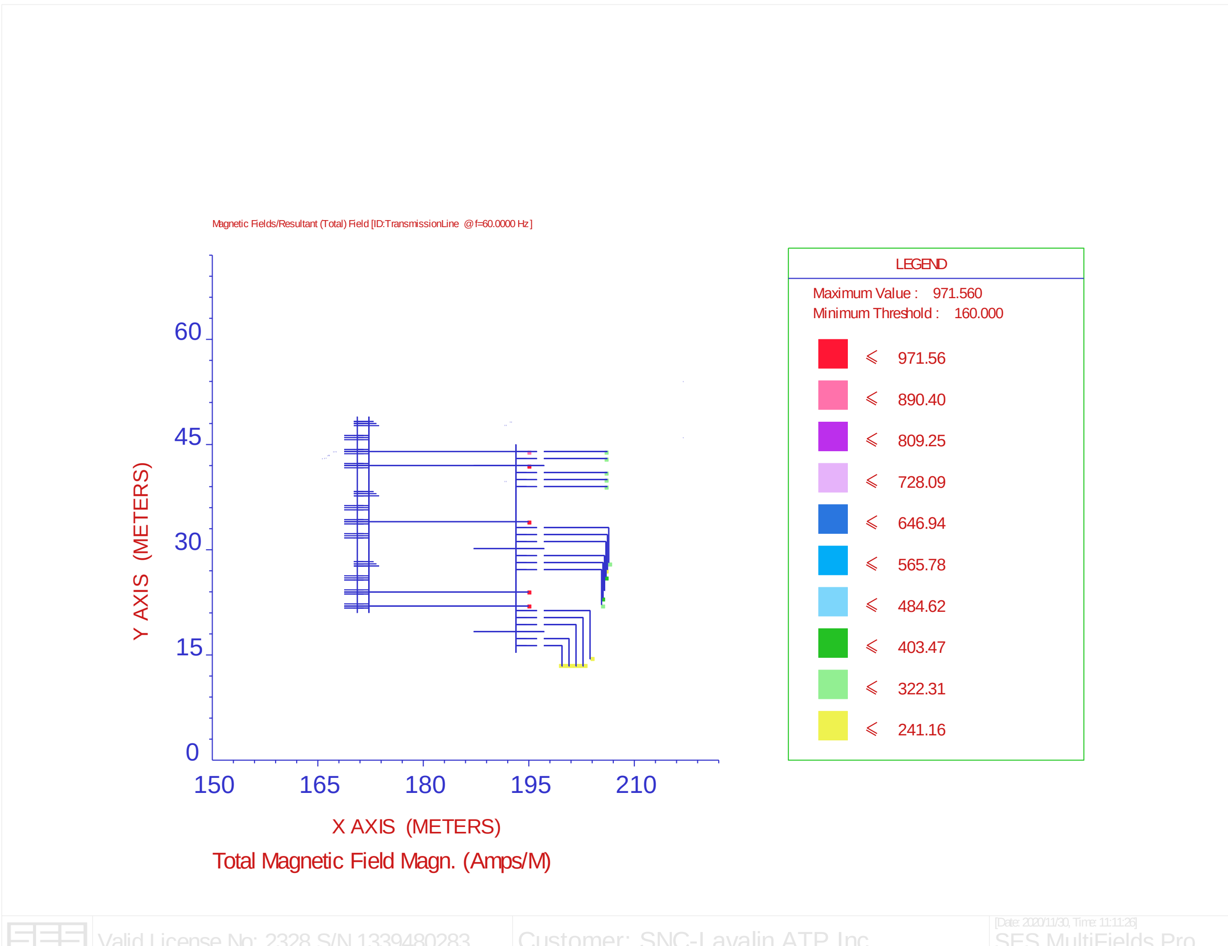

Figure 0-4 Magnetic Field at sea level for OSS2 (1200 MW HVAC)

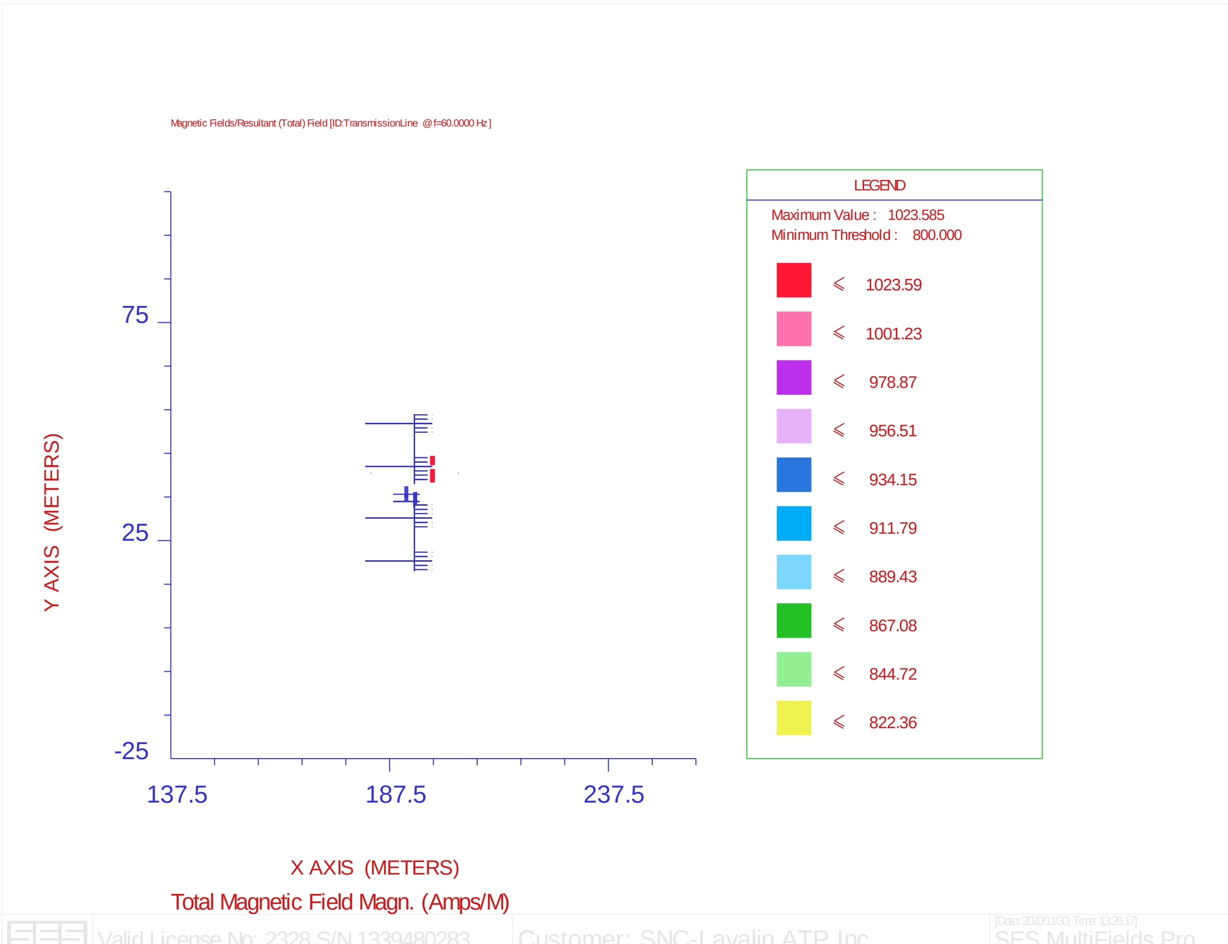

Figure 0-5 Magnetic Field at Deck 1 Level for OSS3 (1200 MW HVDC)

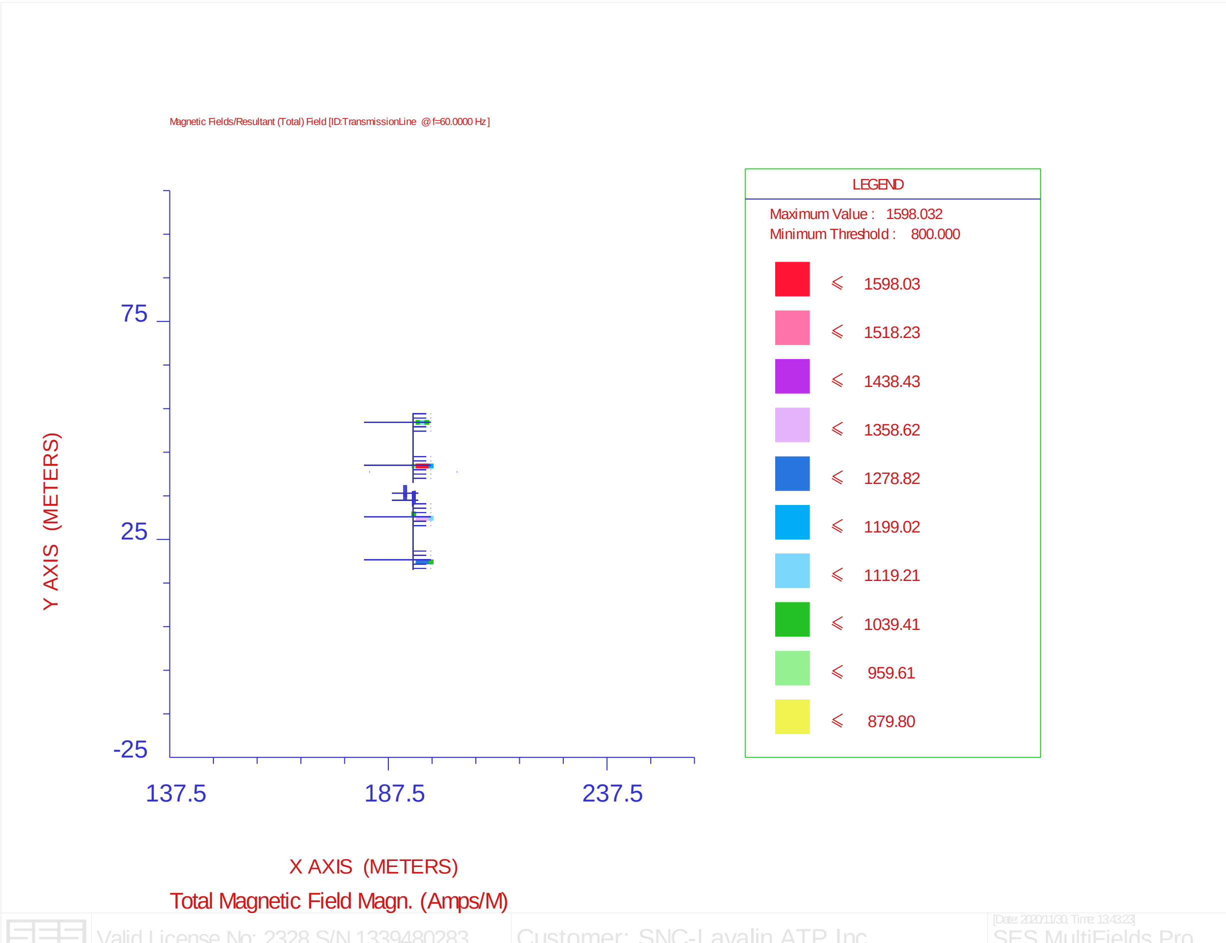

Figure 0-6 Magnetic Field at Deck 2 Level for OSS3 (1200 MW HVDC)

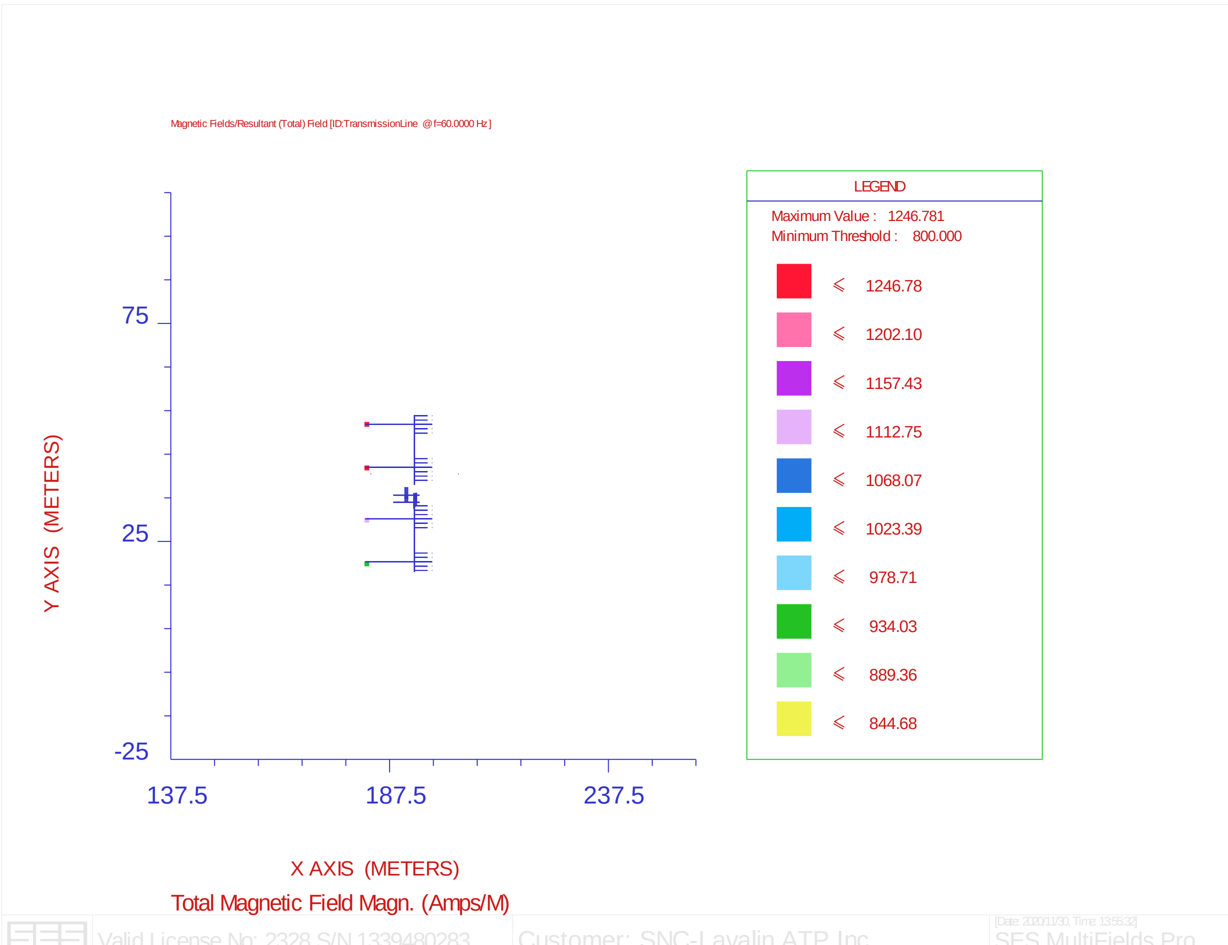

Figure 0-7 Magnetic Field at Deck 3 Level for OSS3 (1200 MW HVDC)

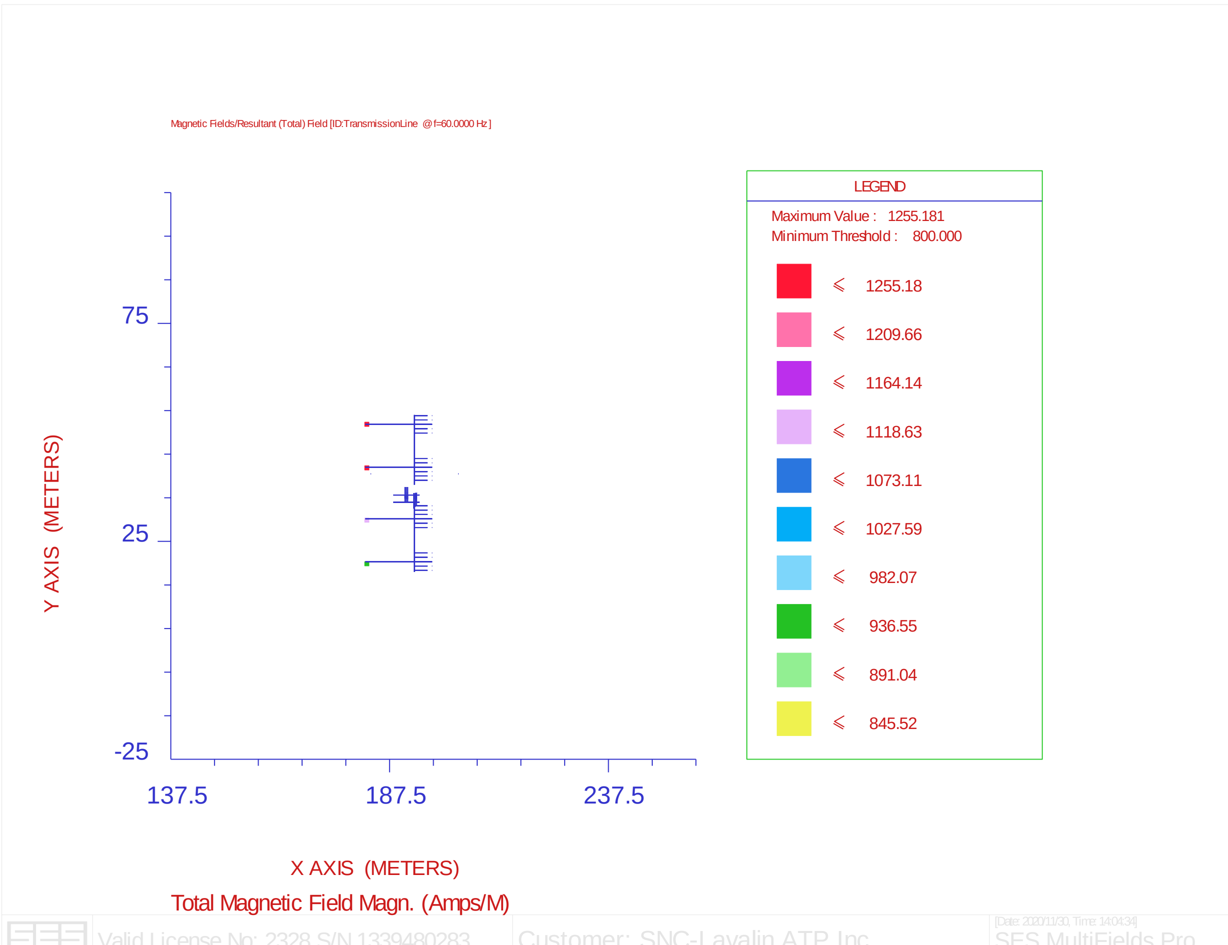

Figure 0-8 Magnetic Field at Deck 4 Level for OSS3 (1200 MW HVDC)

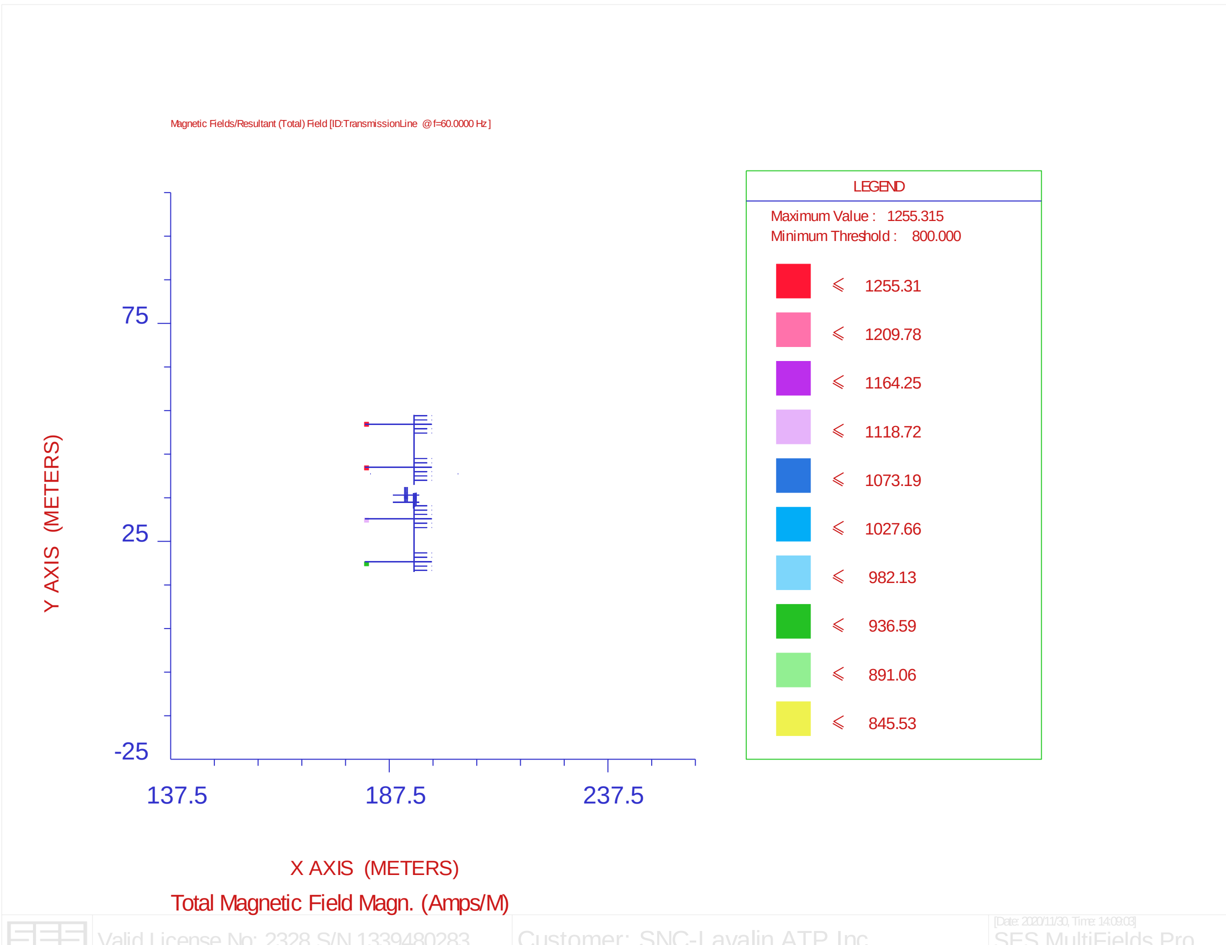

Figure 0-9 Magnetic Field at Deck 5 Level for OSS3 (1200 MW HVDC)

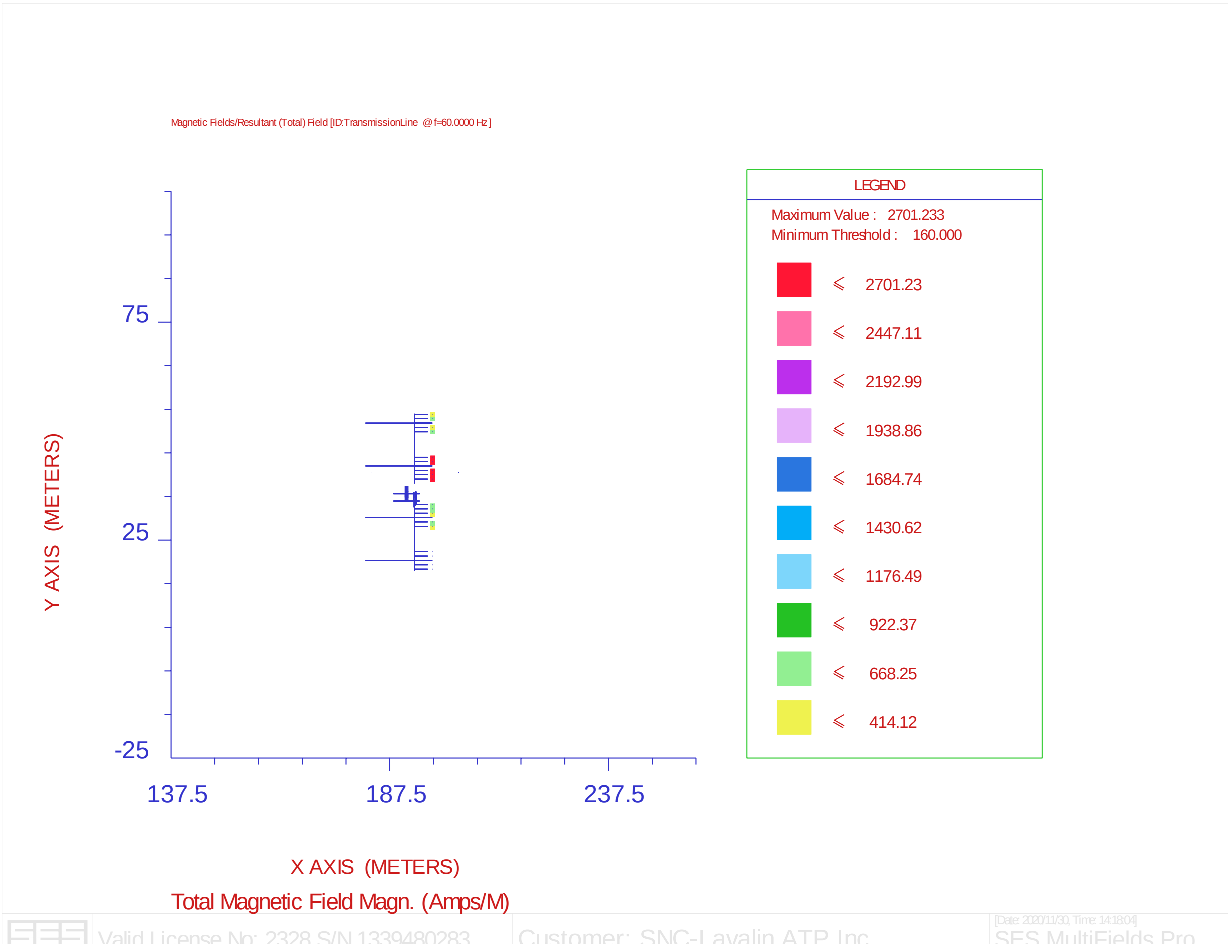

Figure 0-10 Magnetic Field at sea level for AC Cables, OSS3 (1200 MW HVDC)

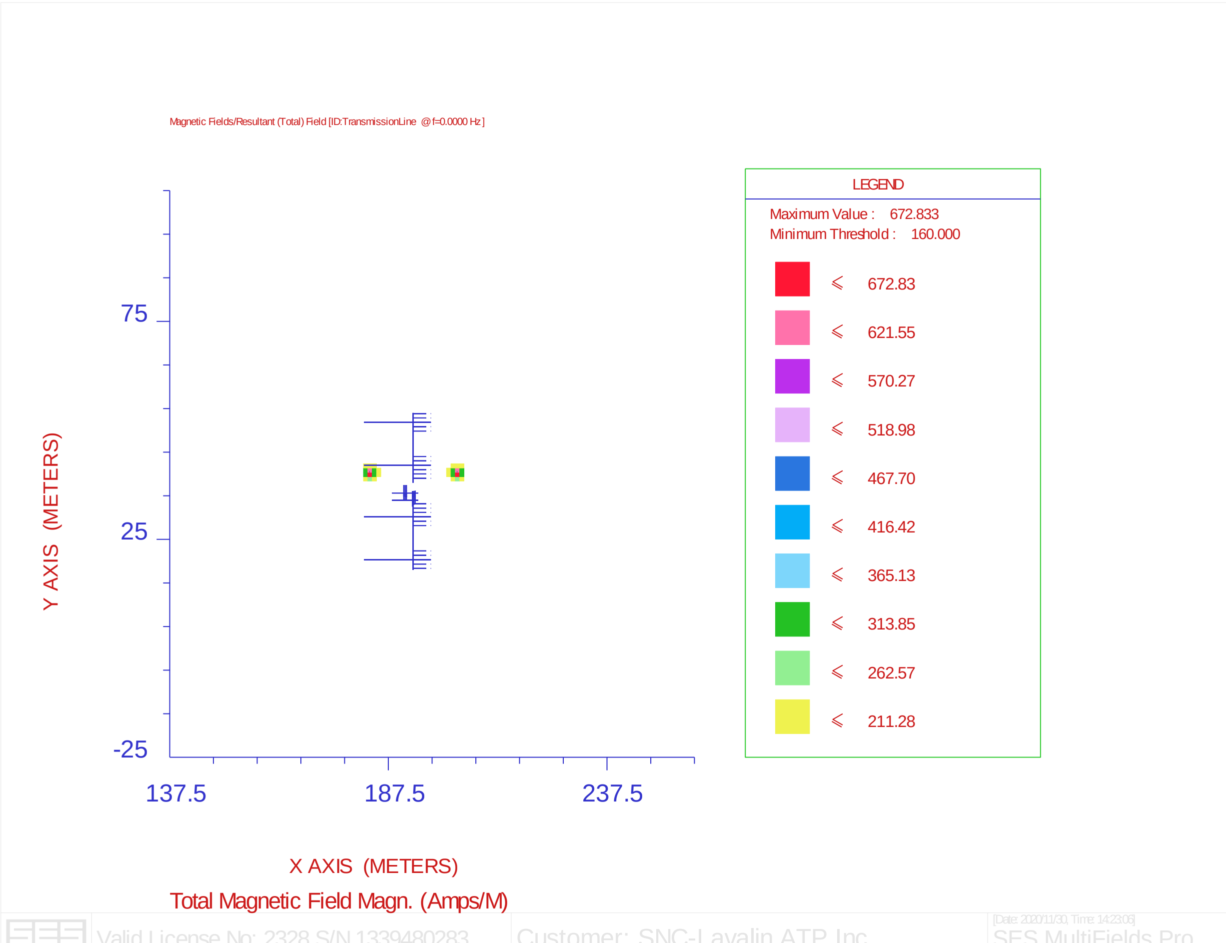

Figure 0-11 Magnetic Field at sea level for DC Cables, OSS3 (1200 MW HVDC)