KINECTRICS

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Calculations of Magnetic Field above 230 kV Underground Cable Line for Dufferin Wind Power Project

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1.0 Executive Summary

The results of calculations show that the calculated magnetic flux density values of the studied 230 kV underground cable configuration do not encroach upon the safety level as stipulated by the World Health Organization guideline (reference 1). The maximum value of the magnetic flux density on the ground surface is 37 μT which is less than even 50% of the allowed magnetic flux density (83 μT). According to the literature, magnetic field at distance of 6 inches from a working microwave oven can be 10 μT to 30 μT and for a vacuum cleaner; this magnetic field can be as high as 70 μT.

The calculated results are only applicable to the proposed installation provided by Genivar and for any change in configuration; it is suggested to redo the calculations.

2.0 Introduction

Kinectrics has studied the magnetic field (MF) generated by the designed 230 kV line. The calculated EMF is based on the provided data and the observation points where the magnetic flux density reaches its highest value.

According to the World Health Organization guideline (reference 1, Table 7) root mean square (RMS) of magnetic flux density B for general public should be kept below 5000/f, where f is the frequency. Therefore for 60 Hz, B = 83 μT (micro Tesla). For occupational workers (power line staff) B = 25000/f = 417 μT.

In this report, the calculations were conducted numerically using finite element method (FEM) and the commercial software COMSOL. The calculations were based on provided data of the cables and installation.

3.0 Information Provided by Genivar

- Cable: 230 kV, 1000 kcmil
- Cable maximum operating conditions for 100 MW:
  - Maximum voltage of 250 kV and 256.6 A
  - Maximum current of 291.6 A and 220 kV
- Cable installations presented in Fig. 1

For magnetic field calculations the highest current value was chosen as the worst case scenario.

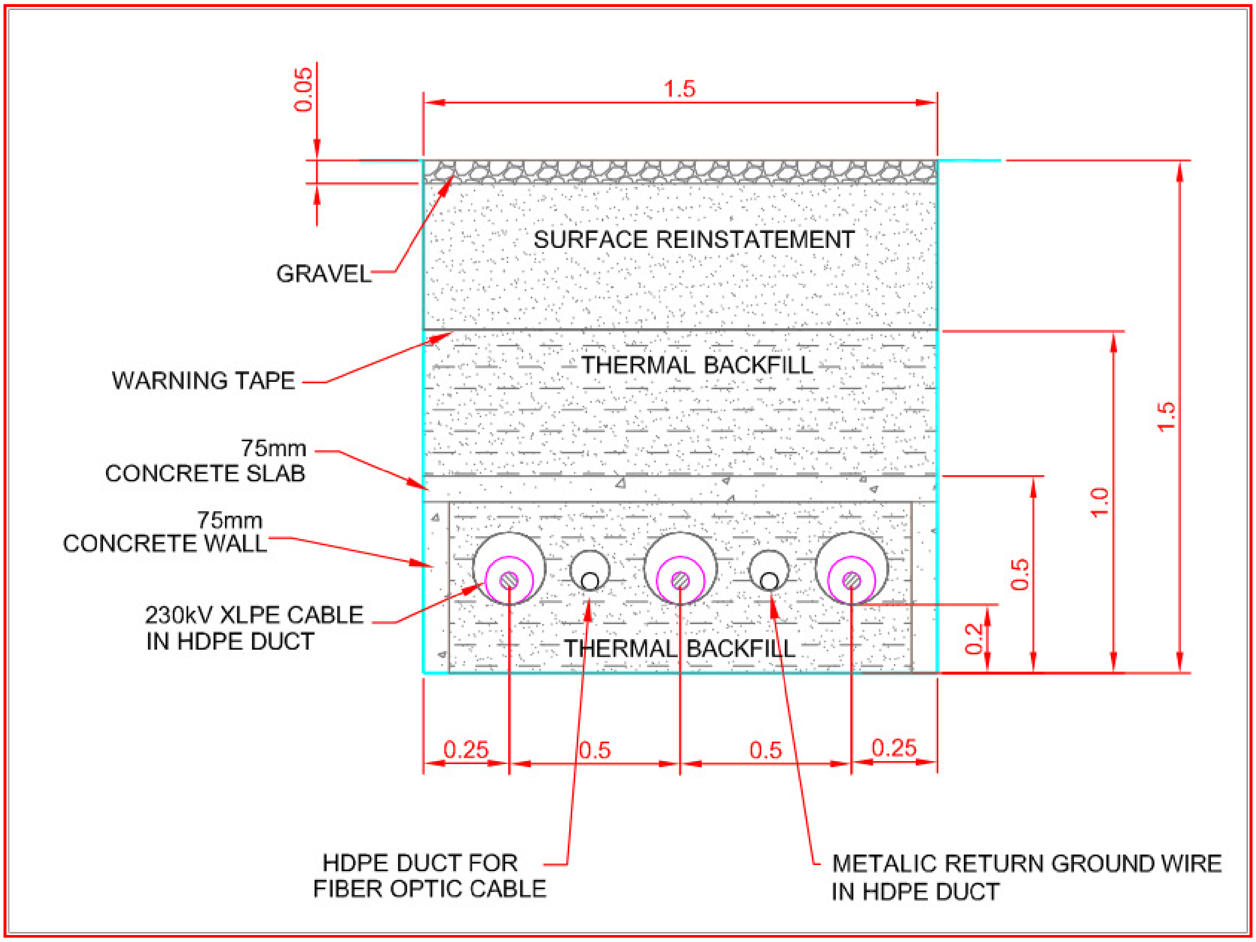

Fig. 1. *Cable installation provided by Genivar*

4.0 Assumptions

The following assumptions were made either due to lack of data or for modeling purpose:

- The currents are symmetrical and sinusoidal.
- Bonding type is of a type that no current flows in the sheath/concentric wires and in metallic return ground wire (single point bonded, cross-bonded). This usually is the worst case since the current in the sheath reduce the magnetic field from the cable.
- No ferromagnetic parts are in vicinity of the cables. All the materials are either para- or diamagnetic.

5.0 Calculation method

For EMF calculations Kinectrics uses commercial software called COMSOL which allows for analysis of such complex installations using finite element method (FEM). Beside EMF analysis, Kinectrics performs thermal rating studies of power equipments and complex cable installations (i.e. tunnels, crossings) using aforementioned software.

The FEM has been described in many textbooks thus will not be provided in this report. The model of the cable installation presented in Fig. 1 includes:

a) graphics,
b) definition of materials,

c) domain settings and boundary conditions, and
d) mesh.

Graphics and mesh are presented in Fig. 2. Materials were defined using their physical properties from the tables. For these calculations the most important parameter is permeability which is 1 for all materials.

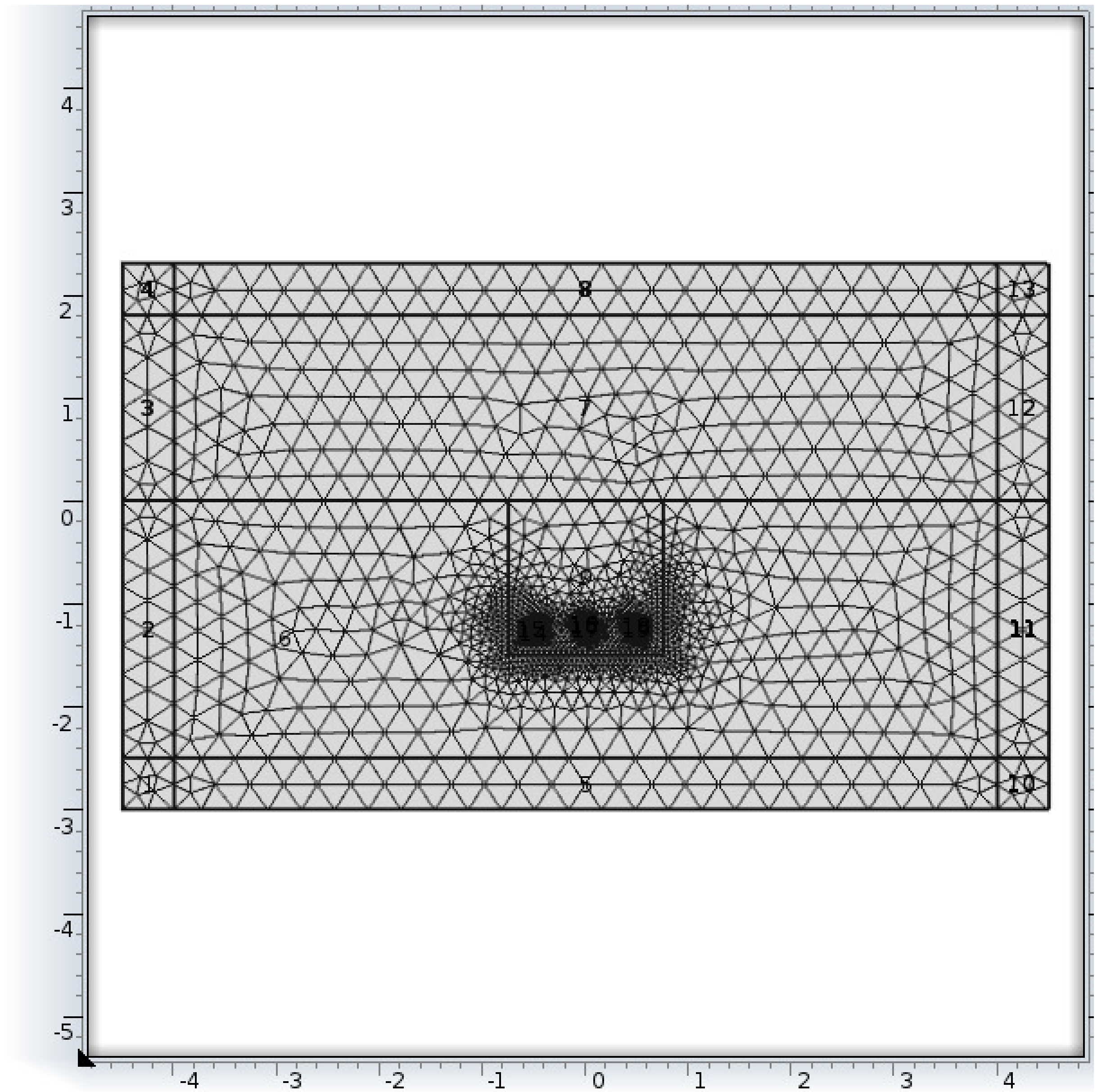

Fig. 2. *Mesh and contours of the cable installation model; the coordinates are expressed in meters [m] (see next figures)*

All domains are subject to Ampere's Law and in addition to this the conductors have the ability to conduct currents thus current density vector had to be defined according to the expected current of 291.6 A and the cross section of 1000 kcmil. The additional setting, called infinite element, is applicable only to the outer rectangles indicated by the numbers (see Fig. 2) 1, 2, 3, 4, 5, 8, 10, 11, 12 and 13. It simulates the field in the infinity.

The boundary conditions are defined only as Magnetic insulation in the infinity, which means no magnetic flux can penetrate through the boundary. This is applicable only to the outer boundary of the model presented in Fig. 2.

6.0 Results

The model presented in Fig. 2 was solved using aforementioned software and the results are presented in Fig. 3 and Fig. 4. The result in Fig. 3 was obtained for the extreme case when the instantaneous currents flow in the most unfavourable way generating the highest magnetic flux. Depending on the phase angle, the currents may flow in different configuration according to 3-phase sinusoidal curves. Fig. 3 shows the results for the phase angle equal zero when there is no current in the middle cable and the same magnitude (peak) but opposite directions in outer cables.

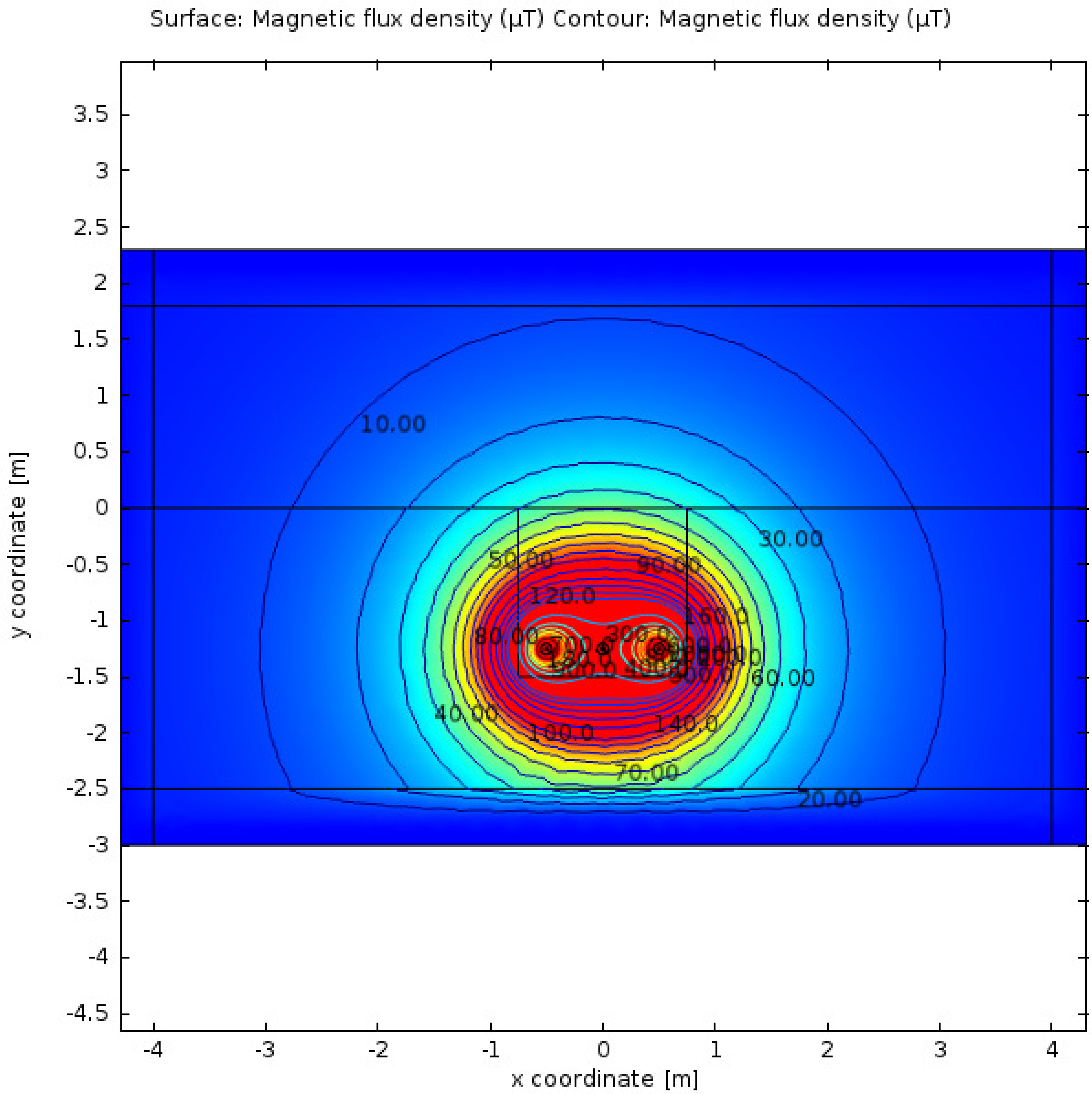

Fig. 3. *Magnetic flux distribution around the cables; Y coordinate=0 symbolizes ground level.*

Fig. 4 shows changes in the magnetic flux density with the phase angle in two locations:

a) on the ground surface, and
b) 1.8 m above the ground.

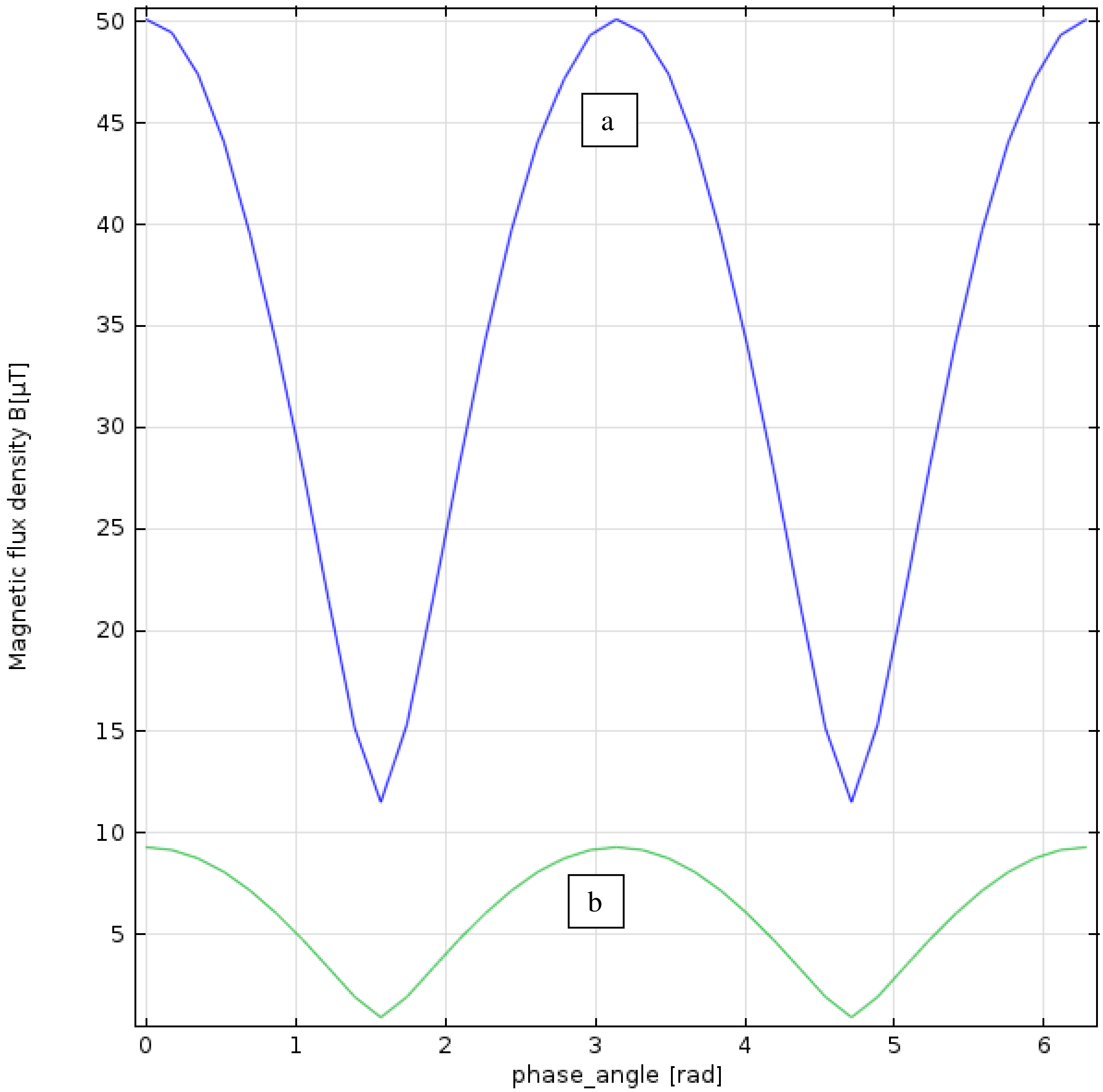

Fig. 4. *Magnetic flux density as a function of the phase angle (which determines an instantaneous value of the current)*

In order to obtain a value comparable to standards one needs to calculate the RMS value of the magnetic flux presented in Fig. 4. The program used for calculations has such capability and the final results are presented in Table 1.

Table 1. Calculated magnetic flux density on the ground and 1.8 above

Calculated magnetic flux density			Allowable magnetic flux density	
	RMS	MAX	RMS	MAX
Ground level	37 µT	50 µT	83 µT	117 µT
1.8 m above ground	7 µT	10 µT		

Figure 5 shows the magnetic field distribution on the ground level (worse case) which shows the maximum right on top of the Trench (37 μT) and as moving away from the Trench, the MF reduces.

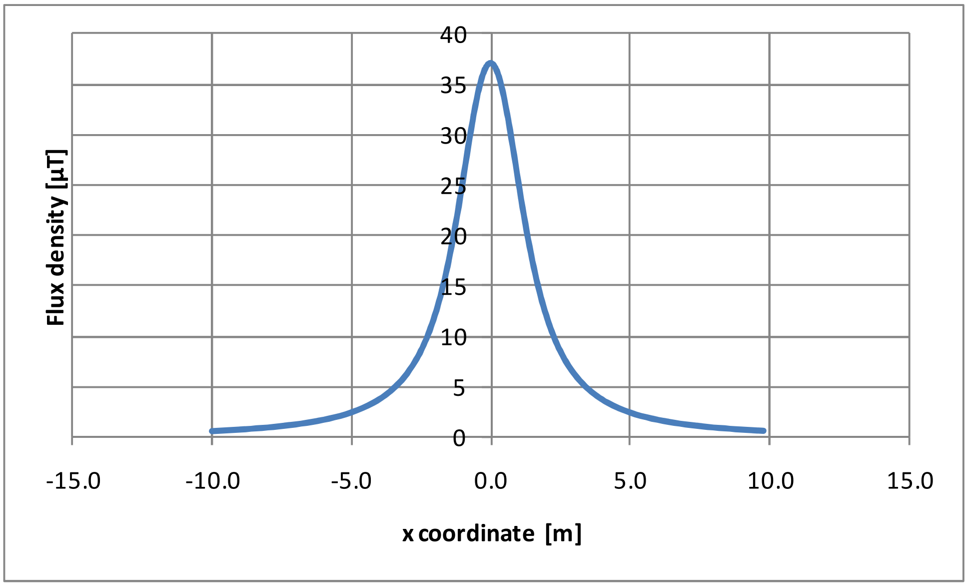

Fig. 5. *RMS magnetic flux density on the ground within the range of ±10 meters from the central cable (in the direction perpendicular to the cable route).*

7.0 Summary and Conclusion

The results of calculations in the two indicated locations show that the calculated RMS magnetic flux density values do not encroach upon the safety level as stipulated by the World Health Organization guideline (reference 1, Table 7). The maximum value of the magnetic flux density on the ground surface is 37 μT which is less than even 50% of the allowed magnetic flux density (83 μT). The magnetic flux density drops significantly as the distance from the cable increases.

According to the literature, magnetic field in a 6" distance from a working vacuum cleaner can be as high as 10 μT to 70 μT and for a microwave oven can be 10 μT to 30 μT.

It has to be mentioned that the results are only applicable to the installation provided in Fig. 1.

8.0 Reference

1- Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields, ICNIRP GUIDELINES, International Commission on Non-Ionizing Radiation Protection, 1998.

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Kinectrics Inc. has prepared this report in accordance with, and subject to, the terms and conditions of the contract between Kinectrics Inc. and Genivar Inc. as per the Kinectrics quote # NAD-417-510-2012.