MAGNETIC FIELDS MANAGEMENT FOR UNDERGROUND CABLES STRUCTURES

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ABSTRACT

Underground cables are identified as one of the main sources of hazardous magnetic fields. These fields produced by distribution cables vary significantly with the installation pattern. Parameters such as the relative position of various conductors and circuits, phase placement, depth of burial, etc affect the magnetic field produced around the cable considerably. Measurements were carried out using different types of field meters to minimize the uncertainty.

The aim of this paper is to investigate the magnetic field in the region located above the cable for various cases and identify the arrangement that gives minimum field for various circuits distribution systems. A simulation technique was used for comparison.

Keywords*: Underground cables, magnetic field measurement, EMF exposure, Distribution cables*

INTRODUCTION

Electric cables are major sources of magnetic field around occupational areas.

Majority of Extremely Low Frequency (ELF)-Electromagnetic Field (EMF) working group members concluded that exposure to EMF is “possible” human carcinogen.

This decision was based largely on “limited evidence” of increasing risk of childhood leukemia with residential exposure and increased occurrence of leukemia associated with occupational exposure.

AIM OF THE PAPER

- To investigate and quantify magnetic fields produced by underground cables
- To examine the effect of various design parameters on magnetic field in the region located above cables structures.
- To identify the rearrangement that gives minimum field for various single – and multiple – circuit distribution systems.
- To Provide Guidelines for best design with minimum magnetic field.

CALCULATION OF DISTRIBUTION CABLES MANGEMENT FIELDS

Calculation were made using computer program dedicated to determine magnetic fields at ground level created by single and multiple conductor distribution cables.

Calculation procedure applied Biot- Savart’s law and superposition to all of the current carrying conductors in a cable circuit.

Magnetic field calculation procedure takes into account the following assumption:

1- The earth has no effect on magnetic field produced by the cable, based on the fact that most materials other than ferromagnetic material have a relative magnetic permeability of very close to unity.
2- Any zero-sequence component of the induced sheath/shield current or the phase conductor current return in the earth at a distance far enough from cable circuit has little effect on magnetic field at the earth’s surface.
3- Each cable is considered to be infinitely long and straight.
4- Total magnetic field at any point may be determined by a linear superposition of the magnetic fields produced by all of the currents in the cable system.
5- There are no stray currents flowing in the cable sheath/ shields or neutral conductor by source other than the current flowing in cable conductors.
6- Current through conductors flows out of the paper.

VARIABLES THAT AFFECT MAGNETIC FIELDS FROM DISTRIBUTION CABLES

1- Magnitude of phase current
2- Depth of conductor below ground
3- Configuration of conductors
4- Lateral distance from cables
5- Neutral and sheath current
6- Proximity of magnetic material and conducting objects.

MAGNETIC FIELD MEASUREMENTS AND SIMULATIONS

Series of measurements have been carried out in this study for different power lines, distribution systems, and underground structures used in residential, commercial and industrial areas, in relation to their magnetic fields. The survey and dosimetry instruments used in the survey were EMDEX II (Electric and Magnetic Field Digital Exposure) meter by (Enertech Consultants). The instrument is supplied with a software package capable of monitoring, recording and analyzing personal exposure to power-frequency electric and magnetic fields. The field sensors are three-orthogonally-mounted sensor coils. The meter can display the magnetic field along the x-, y-, and z-axes (B_x, B_y, and B_z) and the root mean square (RMS) B_{field}.

Simulations were also done for comparison purposes (taking in considerations that the current is 100A). The findings of measurements are thoroughly detailed in this paper and summarized in the following sections

1-Distribution Lines

Sample of distribution line of 11kV magnetic field measurement is shown in Fig.1.Measurements were done using different meters such as EMDEX and Wave Corder meter. The results can be used thoroughly to check the surrounding areas in 3-Dimensional recordings. This work was done for comparison purposes between distribution lines and cables

Fig.1(a). Distribution Line Photo

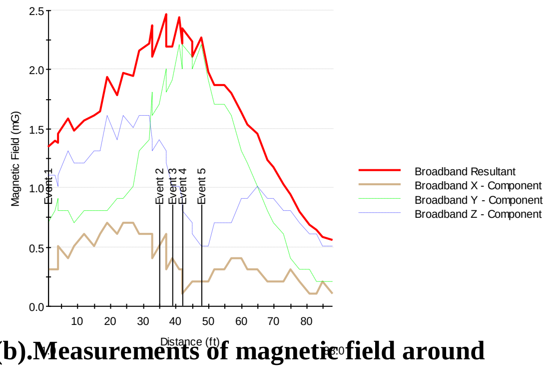


Fig.1 (b).Measurements of magnetic field around Distribution line and Field Components.

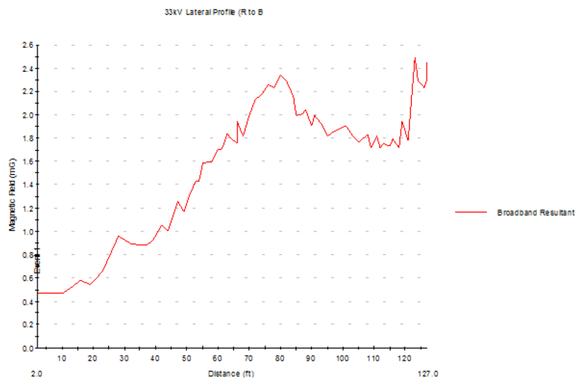


Fig.1(c).Lateral Magnetic Field Measurement of 33kV Distribution Line Using EMDEX

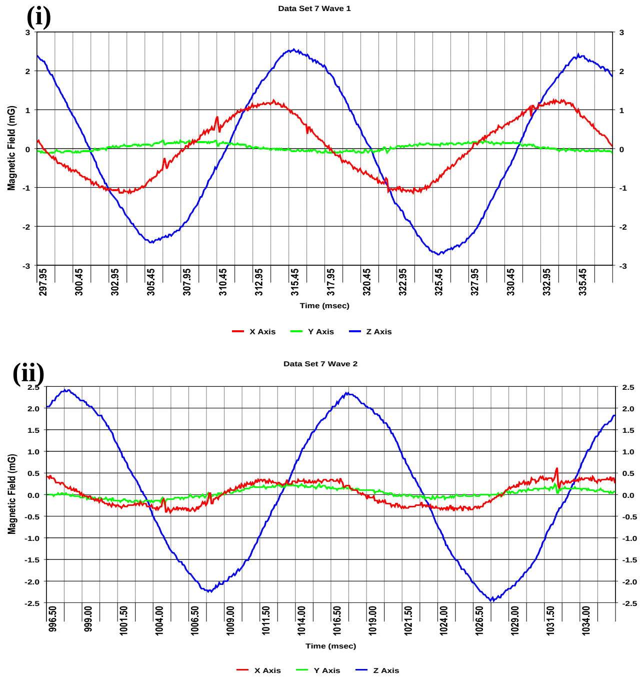


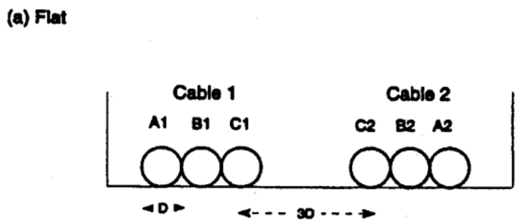
Fig.1(d) Measurement of Magnetic Field using Wave Corder Meter around Distribution Line

2-Underground Cable

Magnetic fields measurements were taken on 11 kV cable circuits.

Simulation of the underground cables using MF3D Software package by EPRI, with all assumptions and same current conditions, Studies on magnetic field management techniques were done by simulation studies including: distance between cables, source geometry, and cable depth. Fig. (2) Shows sample of simulation on Flat and triangle cable settings.

Table (1) shows simulation of magnetic field of 36 feet and 48 feet above street level on center line of cable for different number of cables per phase and different configurations. Fig.(3) shows the effect of depth for single phase cable for different configurations, while Fig.(4) shows the effect of depth for 3-phase cables. Tables (2) and (3) show complete detailed simulation for two cables per phase and three cables per phase configuration respectively.



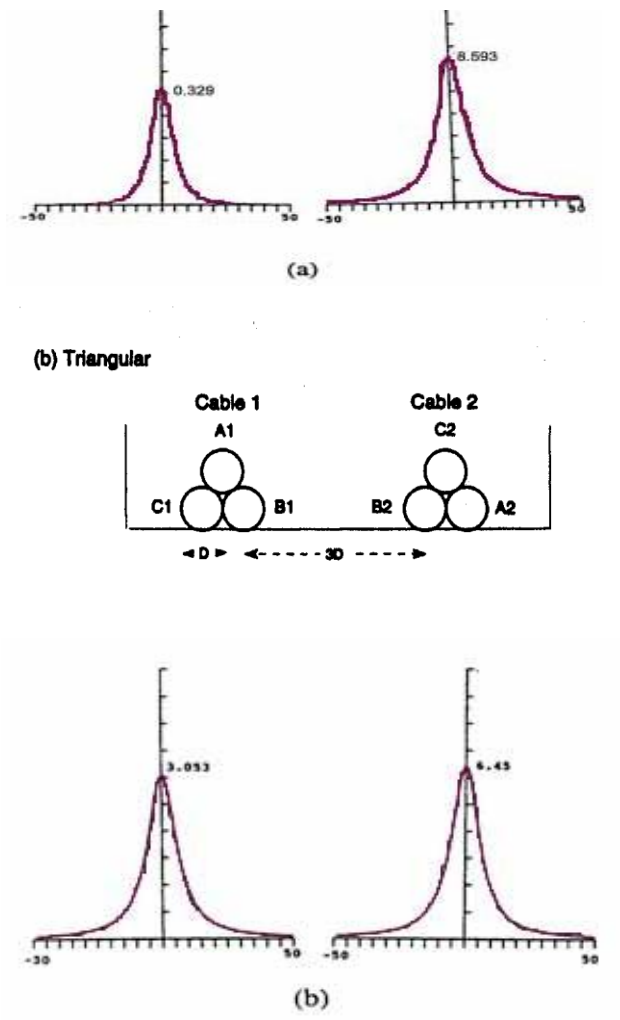


Fig.(2)Details of worst and best magnetic fields for (a)flat arrangement ,(b) triangle arrangement

Table (1).Calculations of Cables Magnetic Field 1 meter above road surface for different depths and number of cables

No. Of cables per phase	Stack (mG)		Triangular (mG)		Flat (mG)	
	Depth of 36 feet	Depth of 48 feet	Depth of 36 feet	Depth of 48 feet	Depth of 36 feet	Depth of 48 feet
2	0.402	0.260	6.509	4.862	1.484	0.995
3	6.586	4.909	9.644	7.217	6.137	0.659
4	0.475	0.305	9.541	7.392	0.783	0.471
5	6.593	4.912	12.793	9.818	4.725	3.609
6	1.490	0.965	15.977	12.207	2.025	1.395

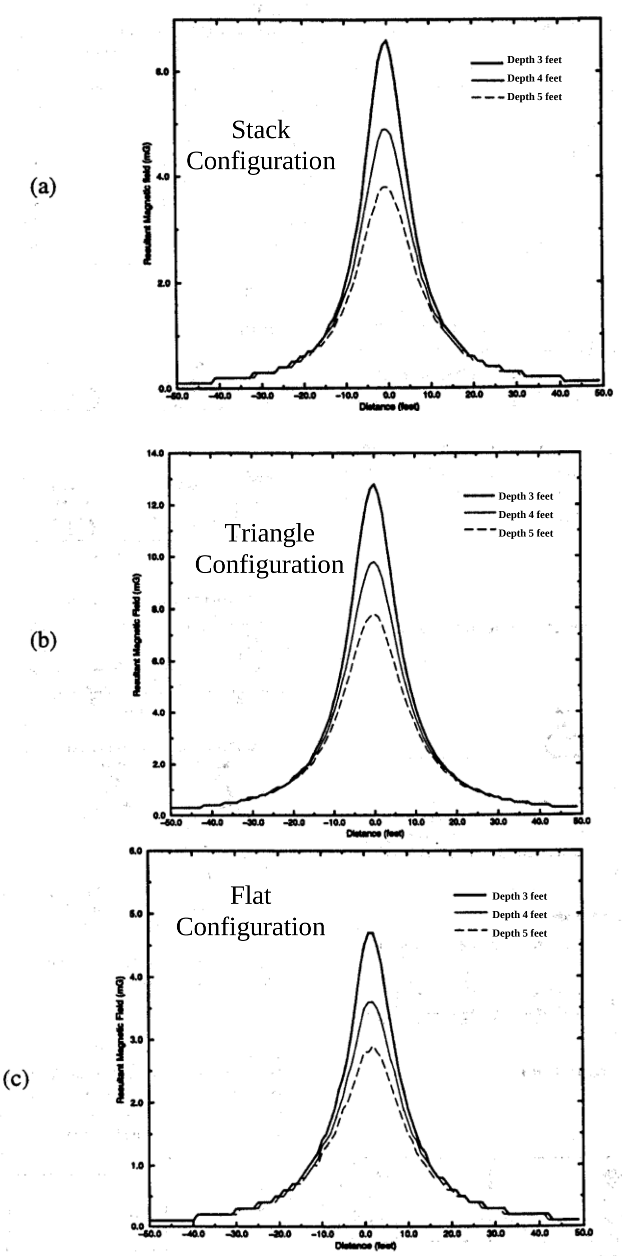
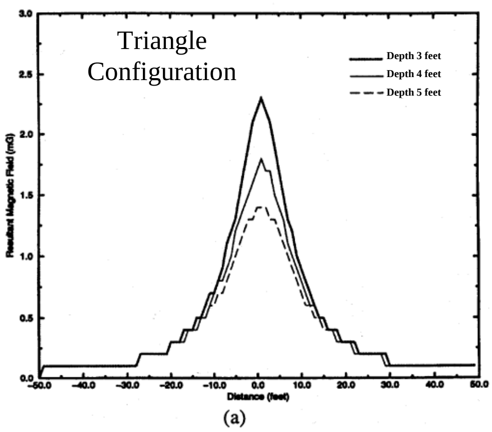
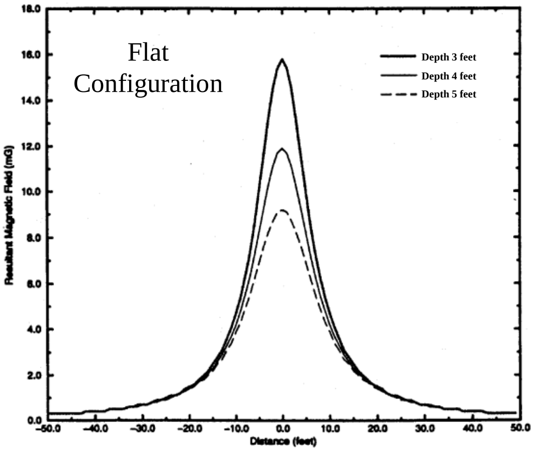


Fig.(3) Effect of Depth for Single Phase Cables





(b)

Fig.(4) Effect of Depth for 3 phase cables

Table (2) Details of possibilities of Magnetic fields for two cables per phase arrangement

Image Conductors	Intermediate Conductors (1)	Intermediate Conductors (2)	Intermediate Conductors (3)	Intermediate Conductors (4)	Inverted Image Conductors
a b b a c c (7.670 mG)	a b a b c c (7.652 mG)	a b a c c b (7.177 mG)	a b c a c b (5.893 mG)	a b c b c a (7.177 mG)	a b b c c a (4.281 mG)
a c c a b b (7.670 mG)	a c a c b b (7.652 mG)	a c a b b c (7.177 mG)	a c b a b c (5.893 mG)	a c b c b a (7.177 mG)	a c c b b a (4.281 mG)
b a a b c c (7.670 mG)	b a b a c c (7.652 mG)	b a b c c a (7.177 mG)	b a c b c a (5.893 mG)	b a c a c b (7.177 mG)	b a a c c b (4.281 mG)
b c c b a a (7.670 mG)	b c b c a a (7.652 mG)	b c b a a c (7.177 mG)	b c a b a c (5.893 mG)	b c a c a b (7.177 mG)	b c c a a b (4.281 mG)
c a a c b b (7.670 mG)	c a c a b b (7.652 mG)	c a c b b a (7.177 mG)	c a b c b a (5.893 mG)	c a b a b c (7.177 mG)	c a a b b c (4.281 mG)
c b b c a a (7.670 mG)	c b c b a a (7.652 mG)	c b c a a b (7.177 mG)	c b a c a b (5.893 mG)	c b a b a c (7.177 mG)	c b b a a c (4.281 mG)

Table (3) Details of possibilities of Magnetic Fields for three cables per phase arrangement

Image Upper Conductors		Intermediate Upper Conductors		Inverted Image Upper Conductors	
a b b a c c a b c (9.007 mG)	a b b a c c a c b (7.645 mG)	a b a b c c a b c (11.378 mG)	a b a b c c a c b (12.269 mG)	a b b c c a a b c (6.381 mG)	a b b c c a a c b (7.236 mG)
a b b a c c b a c (9.147 mG)	a b b a c c b c a (7.567 mG)	a b a b c c b a c (9.262 mG)	a b a b c c b c a (7.560 mG)	a b b c c a b a c (6.962 mG)	a b b c c a b c a (6.558 mG)
a b b a c c c a b (9.535 mG)	a b b a c c c b a (9.385 mG)	a b a b c c c a b (11.600 mG)	a b a b c c c b a (9.541 mG)	a b b c c a c a b (6.862 mG)	a b b c c a c b a (5.014 mG)

Image Upper Conductors		Intermediate Upper Conductors		Inverted Image Upper Conductors	
a b b a c c a b c (9.199 mG)	a b b a c c a c b (7.597 mG)	a b a b c c a b c (11.493 mG)	a b a b c c a c b (12.273 mG)	a b b c c a a b c (6.381 mG)	a b b c c a a c b (7.103 mG)
a b b a c c b a c (9.344 mG)	a b b a c c b c a (7.597 mG)	a b a b c c b a c (9.403 mG)	a b a b c c b c a (7.556 mG)	a b b c c a b a c (7.103 mG)	a b b c c a b c a (6.711 mG)
a b b a c c c a b (9.344 mG)	a b b a c c c b a (9.199 mG)	a b a b c c c a b (11.493 mG)	a b a b c c c b a (9.403 mG)	a b b c c a c a b (6.711 mG)	a b b c c a c b a (4.980 mG)

COMMENTS AND CONCLUSION

Magnetic field produced by underground cable vary significantly with the installation methods and phase placement .Effect of various parameters such as depth , conductor separation , on the produced field are presented There are different conductor layouts for single phase and three phase cable that are recommended by EPRI. There are three types of configuration for single phase cable: Stack, Triangular, and Flat. It was noticed from the calculation that the minimum magnetic field emission value is from the stack configuration and maximum values for triangular configuration for the two cables per phase. Also, the calculation shows that the triangular configuration for 6 cables per phase gives the maximum magnetic field value. For the three phase cable, the triangular configuration gives the minimum magnetic field emission values, while the flat configuration gives the maximum magnetic field emission values. Also, it is noticed that the minimum magnetic field value for two cables per phase arrangement was given for the inverted image conductors (4.281 mG), and the maximum value for the image conductor arrangements (7.67 mG), also the minimum magnetic field value for the three cables per phase arrangement was for the inverted image upper conductors which was 4.98 mG. The results show that the magnetic field decrease with the burial depth increase, but that will be reflected on the cable installation expenses which will increase.

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