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Application of GIS for the Evaluation of Electromagnetic Field Effects for Iraqi 132KV Electrical Transmission System

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Abstract

This research endeavors to create the 50Hz electromagnetic field atlas for populated urban areas in the city of Baghdad (Iraq). For this purpose, the 3-dimensions numerical model based on finite element method (FEM) with time harmonic system is used for simulated and modeling electric and magnetic fields surrounding the 132kV transmission system. The calculated magnetic and electric field levels are compared to exposure guidelines given by International Commission on Non-Ionizing Radiation Protection (ICNIRP). To assign the dangers regions in the city, the properties of the Geographical Information System (GIS) were used. The GIS map highlighted visually the unsafe zones and facilitate the extraction of the electric and magnetic field levels of exposure.

Keywords: Electromagnetic fields, Finite Element Method (FEM), Geographical Information System (GIS), Iraqi Transmission System.

تطبيق نظام المعلومات الجغرافي GIS لتقييم تأثيرات المجال الكهرومغناطيسي لنظام النقل الكهربائي العراقي 132KV

الخلاصة

يهدف هذا البحث الى خلق اطلس للمجال الكهرومغناطيسي ذي التردد 50Hz للمناطق الحضرية المأهولة بالسكان في مدينة بغداد (العراق). لهذا الغرض استخدم نموذج عددي ثلاثي الابعاد مستند على نظرية العنصر المحدد مع نظام زمني توافقي لمحاكاة ونمذجة المجالات الكهربائية والمغناطيسية المحيطة بنظام نقل الطاقة 132kV , ومن ثم مقارنة مستويات المجال المغناطيسي والكهربائي وفقا لحدود التعرض المعتمد من قبل اللجنة الدولية على الحماية من الاشعاع غير المتأين (ICNIRP). تم استخدم نظام المعلومات الجغرافي (GIS) في تخصيص مناطق الاخطار في المدينة حيث انجزت خريطة GIS وبشكل بصري للمناطق غير الامنة وسهولة استنتاج مستويات التعرض للمجالين المغناطيسي والكهربائي.

1. Introduction

In recent years, human exposure to power frequency electric and magnetic fields has increased due to the increased demands for the provision and consumption of Electricity advances in technology and changes in social behaviors. The Creation of new city centers increases the demand for more energy to support commercial and industrial need as well as power for residential areas. Transmission and distribution substations built in areas of high

Population will inevitably create health concern to people living nearby [1, 2].

In this respect, the technological advances have covered the electromagnetic field instrumentation for accurate measurement and advanced modeling for computer simulation, mainly because the increasing numbers of diseases as

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cancer and leukaemia that are interrelated and the publishing of guidelines by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) [3].

On the other hand, Geographic Information Systems (GIS) seem to be a promising means to support organizations in the monitoring activities. Indeed, GIS technology integrates common database operations such as query and statistical analysis of data coming from measurement tools with the unique visualization and geographic analysis benefits offered by maps. Scientific organizations involved in the evaluation of biological effects of electromagnetic field would greatly benefit from a uniform and structured information base, giving details of all electromagnetic field sources in a given area, in activities like sitting-planning of base stations or sources like power lines [4-6].

The present work focuses on the urban environment. Except for 132kV power transmission systems which are normally found by the outskirts of Baghdad city, most electric and magnetic fields are generated by overhead transmission lines. Computer simulation is applied 3-dimensional FEM in the time harmonic mode that is developed by ANSYS software environment, the model results were then exported back into the GIS. The satisfactory simulation results are identify potential areas of high risk due to excessive electromagnetic fields that might be harmful to people or livestock living nearby were complied with the safe limits of such exposure.

2. Numerical Model

In the low-frequency region, the electromagnetic wavelength is much larger than the dimensions of the computational domain such that wave propagation phenomena can be neglected. Consequently, the electromagnetic fields are described by quasi-static Maxwell's equations. The quasi-static approximation allows the assumption that only one field is dominant and thus it is possible to de-couple the electric and magnetic relations and only consider the dominant field [7].

A.Finite Element Formulation

When no magnetic excitation is present, the induced currents can be neglected with respect to the conductive and the dielectric currents, resulting in the so-called *electroquasistatic* approach [8]. In this case, the electric field strength *E* is curl-free: $\nabla \times E = 0$. With the assumption of no electric charges in the computational domain, the displacement current *D* is divergence free: $\nabla \cdot D = 0$. The electric field contains no rotational components. Hence, it can be expressed by the gradient of the electric scalar potential *V* as

$$E = -\nabla V \qquad (1)$$

In a similar fashion, the magnetic field *B* may be expressed as a magnetic vector potential *A*, that is defined by [9]:

$$B = \mu H = \nabla \times A : \nabla \cdot A = 0 \qquad (2)$$

The governing equations for vectors of magnetic field *H* and electric field *E* in a quasistatic system are:

$$\nabla \times H = J \quad (3)$$

$$\nabla \times E = -\frac{\partial B}{\partial t} \quad (4)$$

The electric field can be written in terms of the magnetic vector potential *A* and the electric scalar potential *V* as

$$E = -\nabla V - \frac{\partial A}{\partial t} \quad (5)$$

The finite element method was used for the numerical solution of the vector potentials.

B. Boundary Conditions and Simulation Parameters

This research is to focus on a power transmission system in Baghdad zone (Iraq), especially double- circuit, 132-kV overhead power transmission line, vertical configuration using Twin ACSR “Teal” 2-bundled phase conductor (Overall diameter=25.25 mm) as illustrated diagrammatically by Figure 1. while overhead ground wires (OHGW) are ACSR 'Dorking' (Overall diameter = 16.02 mm) [10].

The boundary conditions applied here are that both electric and magnetic fields at the ground level and the OHGW are set as zero. In contrast, the boundary conditions at the conductor surfaces are practically different. They are strongly dependent upon the load current for the magnetic case. However, in this paper, the boundary conditions of both electric and magnetic fields of conductor surfaces in 132-kV power lines are assigned as given in [11], under the maximum loading of 1000A/phase. This simulation uses the system frequency of 50 Hz. The power lines are bared conductors of Aluminum Conductor Steel Reinforced (ACSR), having the conductivity (σ) = 0.8×10^{7} S/m, the relative permeability (μ_r) = 300, the relative permittivity (ε_r) = 3.5. It notes that the free space permeability (μ_0) is $4\pi\times10^{-7}$ H/m, and the free space permittivity (ε_0) is 8.854×10^{-12} F/m. The case study has been modeled and simulated by using ANSYS software (Revision 11).

The model results were then exported back into the Geographic Information System (GIS). These kinds of calculations help to identify potential areas of high risk due to surface loading.

3. The Geographic Information System (GIS)

A GIS is a powerful computer mapping and analysis technology that allows large quantities of information to be viewed and analyzed within a geographic context [12]. A GIS ". . . links nongraphic attributes or geographically referenced data with graphic map features to allow a wide range of information processing and display operations as well as map production, analysis and modeling." These techniques allow the researcher to go beyond the simple mapping of any problem GISs are used to input, store, manage, analyze, and display data. Many GIS experts believe that a true GIS differs from desktop mapping systems in that it contains a data structure that stores information about topology, i.e., the relationships among geographic features [13]. Certain methods of spatial analysis require a topological data structure, which allows concepts such as adjacency and connectivity, easily visible to humans, to be recognized by a GIS.

Geographic information systems (GIS) are being used with increasing frequency in environmental epidemiology studies. Reported applications include locating the study population by geocoding addresses (assigning mapping coordinates), using proximity analysis of contaminant source as a surrogate for exposure, and integrating environmental monitoring data into the analysis of the health outcomes. Although most of these studies have been ecologic in design, some have used GIS in estimating environmental levels of a contaminant at the individual level and to design exposure metrics for use in epidemiologic studies [14].

In this work, GIS was used as a tool to assign the dangers regions in Baghdad city according to the distribution of the high voltage transmission lines and their electromagnetic effects.

4. Building the GIS- Model for the Study Area

This part of the work is divided into two steps; those are the building of the GIS layers and the analysis of the electromagnetic field levels by ATLAS mapping.

A. Mapping the Base Data

Two fundamental digital map layers are necessary to perform this research. One was a point coverage representing location of the 132-kV power stations. The other was a line coverage representing the location of the 132-kV transmission lines in study area. These two digital map layers are illustrated in Figure 2 and Figure 3 respectively.

B. Analysis the Electromagnetic Field Levels

The double circuit is considered by the maximum permissible load current and assumed to be normal loading case. In our case, the corresponding phase currents are:

$$I_A = 1000\angle 0^{\circ}\,[A]$$

$$I_B = 1000\angle 120^{\circ}\,[A]$$

$$I_C = 1000\angle -120^{\circ}\,[A]$$

Figure 4 and Figure 5 show the modeling results of magnetic and electric fields of zone under study at a height of (1–3) meters above ground.. By collection the numerical results, an ATLAS is prepared showing the electric and magnetic fields round the transmission lines.

Two buffers layers were created to show some important electric and magnetic fields ATLAS Maps. The first one represent the magnetic field concentration, it was divided into several regions depending on the value of the magnetic field and with different colors as shown in Figure 6. Table 1 summarized modeling results of magnetic field distribution through distances are randomly chosen from center line at a height of 1 meter above ground.

The second one is the electric field concentration, with deferent levels and graduate colors depending on the value of the electric field (the darker region is the most dangers region) as shown in Figure 7. Table 2 summarized modeling results of electric field distribution through distances are randomly chosen from center line at a height of 1 meter above ground.

5. Discussion

Notice that the urban levels of the magnetic flux density detected in the present work are in general higher than those found in the standard threshold of ICNIRP, which the level of time-varying magnetic field safe to human for general public up to 24 hours/day must not greater than 0.1µT (1mG) and for occupational whole working day must not over 0.5µT (5mG).

It is clear from Figure 6 the higher values of magnetic field are located at distance from center line to ±25m line sides. Notice that the maximum value is about 245mG at center line at 1m height and with the maximum load.

The mean overall levels of the magnetic flux density found in the present study, 114mG level, which is exceed the standard threshold of ICNIRP .From the obtained results it is very clear that there are very dangers places in Baghdad such as parts of Alsader city in the Alrisafa side of Baghdad and Aldora in the Alkarkh side of Baghdad. The concentration of the magnetic field is very high in these places that would affect the health of the people, especially in the regions that have a double transmission lines, this would doubled the effect of the fields in these regions as shown in Figures (8-9).

The second case study reflects similar conditions faced in first case study where electric field exposures are related to the proximity of 132KV transmission line and, while generally similar to residential exposures, can be seem in Figure 7. For illustration, the higher values of electric field are located at distance from center line to ±50m line sides. The mean overall level of the electric field found in the present study, 0.74KV/m level, which is below the reference levels of ICNIRP.Two sites have been chosen to verify electric field levels analyses from GIS ATLAS Map (Alyarmok, Alkadmya districts in Alkarkh side of Baghdad) as shown in Figures (10-11).

On the basis of the present results, the contribution of the electric and magnetic fields in the urban environment to the occupational exposure of those workers who work in the urban environment can be estimated. The authors recommended the replacement of the over head transmission line by underground cables in these areas.

6. Conclusions

The modeling approach (FEM) has been used to feed the GIS mapping with data needed to analysis the distribution function of the electric and magnetic fields generated by 132 kV in the urban environment in Baghdad city. The analysis of ATLAS mapping for the electric and magnetic field levels, which is provide grouped estimates based on reasonable buffer sizes.

The results of the normal loading case revealed that the magnetic fields at a level of 1m above the ground that is assumed to be the level of human working, do excess the maximum allowance when compiled with the ICNIRP standard.

GIS allowed the preparation of ATLAS mapping. These mapping found hundreds of people living within 100m from center line that the electromagnetic intensity of the double circuit 132KV transmission line is normally stronger than other GIS buffers. Especially for those people who work and live outdoors parts of Alsader city in the Alrisafa side of Baghdad and Aldora, Alyarmok and Alkadmya in the Alkarkh side of Baghdad. These results support the notion of environmental equity for this potential health hazard in this case study area.

References:

[1] Lindgren M, Gustavsson M, Hamnerius Y, Galt S (2001) “ELF magnetic fields in a city

environment" ,Bioelectromagnetics 22:87-90.

[2] d'Amore G, Anglesio L, Tasso M, Benedetto A, Roletti S (2001) "Outdoor background ELF magnetic fields in an urban environment", Radiat Prot Dosim 94(4):375-380.

[3] International Commission of Non Ionizing Radiation Protection (ICNIRP), "Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic and Electromagnetic Fields (up to 300 GHz)," *Health Phys.*, Vol. 74, No. 4, pp.494-522, 1998.

[4] A. Turgeon , P. S. Maruvada, "Application of GIs for the Evaluation of Human Exposure to Magnetic Field in the Vicinity of Power Lines", Institut de recherche d'Hydro-QuCbec (IREQ) Varennes, QuCbec, Canada D.L. Goulet Environment Management Department, Hydro-QuCbec,1998 IEEE.

[5] Ballance, D. Stephenson, R. A. Chapman and J. Muller, "A geographic information systems analysis of hydro power potential in South Africa", Journal of Hydro informatics, 02.4,2000, IWA Publishing 2000.

[6] Luca Paolino, Monica Sebillo, Genoveffa Tortora, and Giuliana Vitiello M. Tucci , "Monitoring Electromagnetic Pollution: A GIS-Based Visual Approach", (Ed.): MDIC 2001, LNCS 2184, pp. 90-101, 2001, Springer-V erlag Berlin Heidelberg 2001.

[7] R. G. Olsen and P. S. Wong, "Characteristics of Low Frequency Electric and Magnetic Fields in the Vicinity of Electric Power Lines", IEEE Trans. on Power Delivery, Vol. 7, No. 4, p p. 2046-2055 , 1992.

[8] S. Reitzinger, U. Schreiber, and U. V. Rienen, "Electro-quasi-static calculation of electric field strength on high-voltage insulators with an algebraic multigrid algorithm," *IEEE Trans. Magn.*, vol. 39, pp. 2129–2132, 2003.

[9] Hasselgren L., Moller E., Hamnerius Y., "Calculation of Magnetic Shielding of a Substation at Power Frequency Using FEM", IEEE Transactions on Power Delivery, Vol. 9, No. 3, 1994.

[10] Ministry of Electricity, Iraq, "Iraq Super Grid Projects 132 kV Single and Double Circuit Steel Tower Transmission Lines", Volume 1 Technical Specification, 2006.

[11] G.B. Iyyuni and S.A. Sebo, "Study of Transmission Line Magnetic Fields," *Proceedings of the Twenty-Second Annual North American, IEEE Power Symposium*, pp.222-231, 1990.

[12]Antenucci JC, Brown K, Croswell PL, Kevany MJ, "Geographic Information Systems: A Guide to the Technology", New York:Van Nostrand Reinhold, 1991.

[13] Goodchild MF, "The state of GIS for environmental problem-solving. In: Environmental Modelling with GIS (Goodchild MF, Parks BO, Steyaert LT, eds)", New York:Oxford University Press, 1993;8-15.

[14] Mini-Monograph: "Information Systems Using Geographic Information Systems for Exposure Assessment in Environmental Epidemiology Studies" ,John R. Nuckols, Mary H. Ward, and Lars Jarup, March 25, 2004.

Table (1) Intensity Magnetic Field for Different Position Cases at High 1m

X(meter)- Right Distance from center line	Magnetic Field B(mG)	X(meter)- Left Distance from center line	Magnetic Field B(mG)
200	$7.1375*10^{-10}$	-200	$2.5291*10^{-10}$
175	$3.5998*10^{-11}$	-175	$5.2896*10^{-12}$
150	$7.2401*10^{-11}$	-150	$1.0652*10^{-10}$
125	$2.1558*10^{-10}$	-125	$1.114*10^{-10}$
100	$3.9174*10^{-9}$	-100	$3.5976*10^{-9}$
75	$3.5393*10^{-6}$	-75	$2.1412*10^{-6}$
50	0.0024654	-50	0.0014823
25	1.7104	-25	1.0294
10	58.807	-10	47.525
5	178.13	-5	135.58
1	226.02	-1	216.38

Table (2) Intensity Electric Field for Different Position Cases at High 1m

X(meter)- Right Distance from center line	Electric Field E(KV/m)	X(meter)- Left Distance from center line	Electric Field E(KV/m)
100	$0.20476*10^{-1}$	-100	$0.20475*10^{-1}$
75	0.025820	-75	0.025819
65	0.051427	-65	0.051424
50	0.14834	-50	0.14834
45	0.21690	-45	0.21689
35	0.50161	-35	0.50161
25	0.13728	-25	0.13728
15	0.45590	-15	0.45609
10	0.72641	-10	0.72771
5	0.87594	-5	1.0214
1	1.5269	-1	1.5261

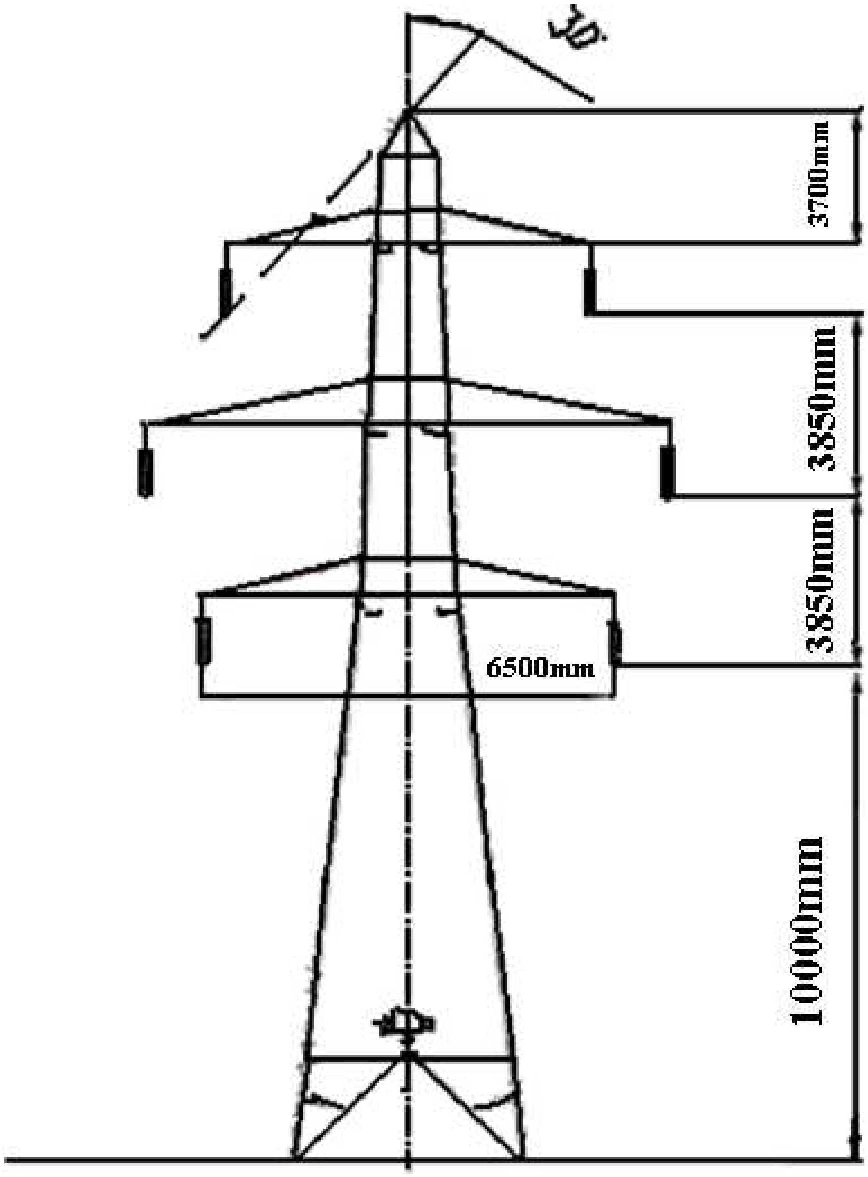

Figure (1) Double Circuit 132 KV Transmission Line [10]

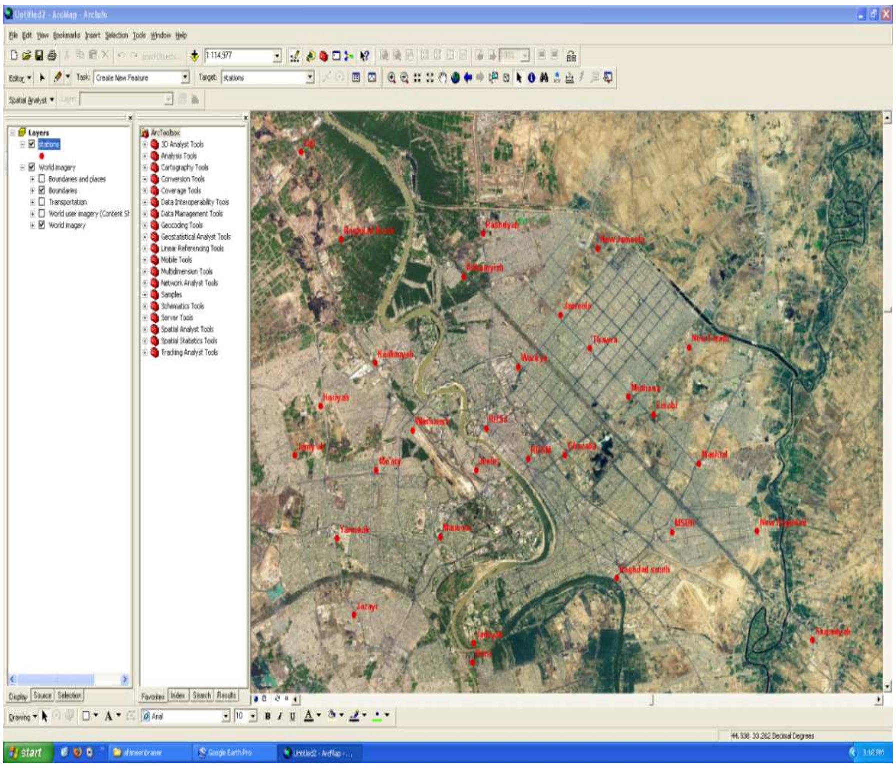

Figure (2) 132 KV Power Stations' Layer

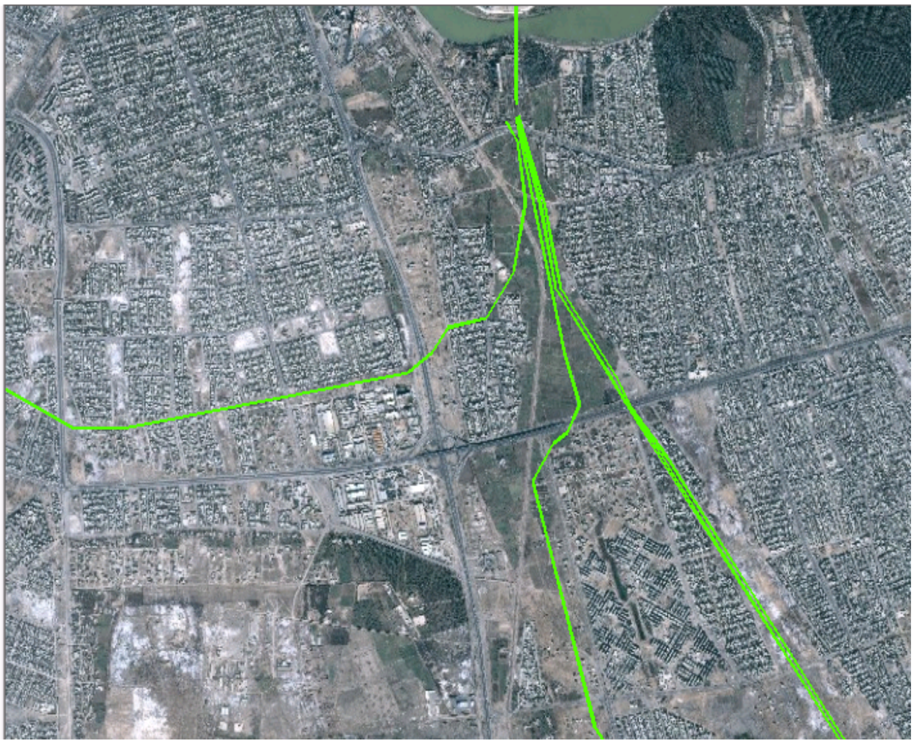

Figure (3) 132 KV Transmission Lines' Layer

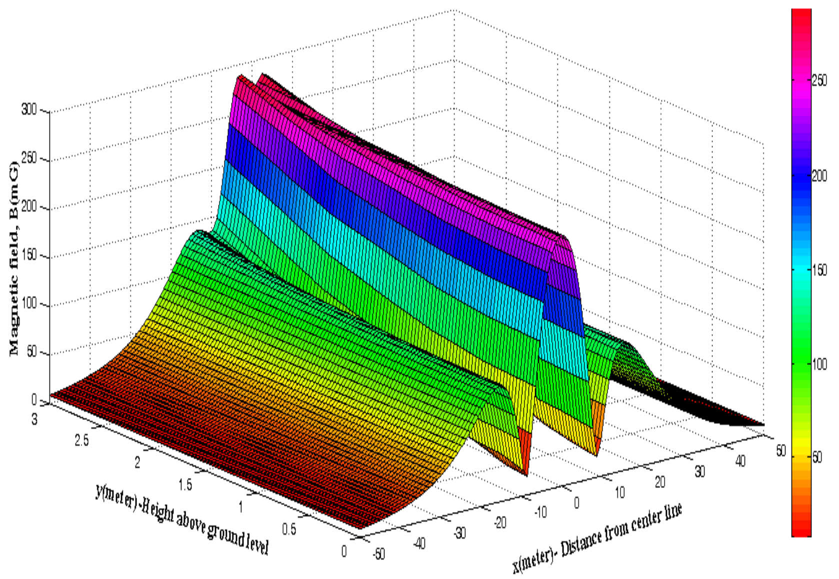

Figure (4) Distribution of the Magnetic Field of Zone Case Study

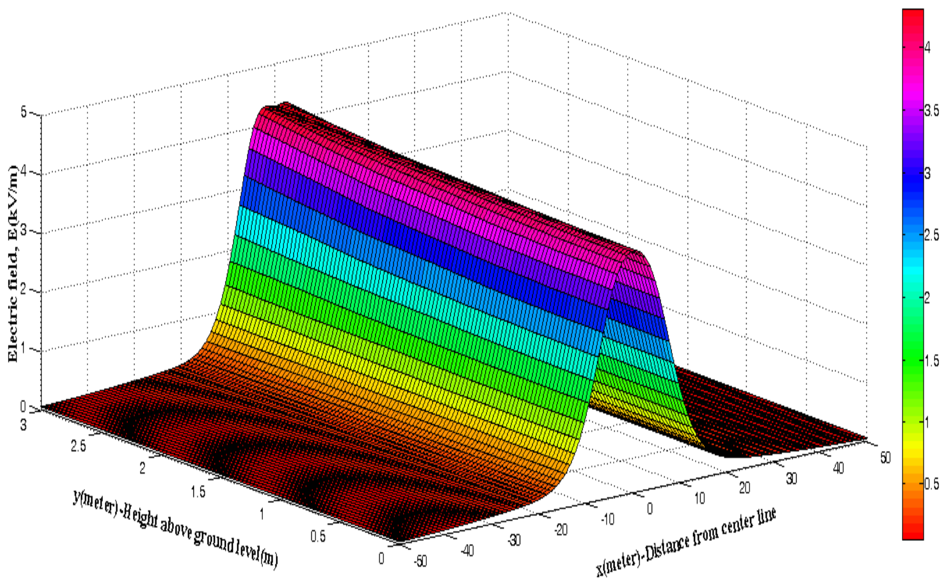

Figure (5) Distribution of the Electric Field of Zone Case Study

Figure (6) The Magnetic Field Buffers Layer

Figure (7) The electric field buffers layer

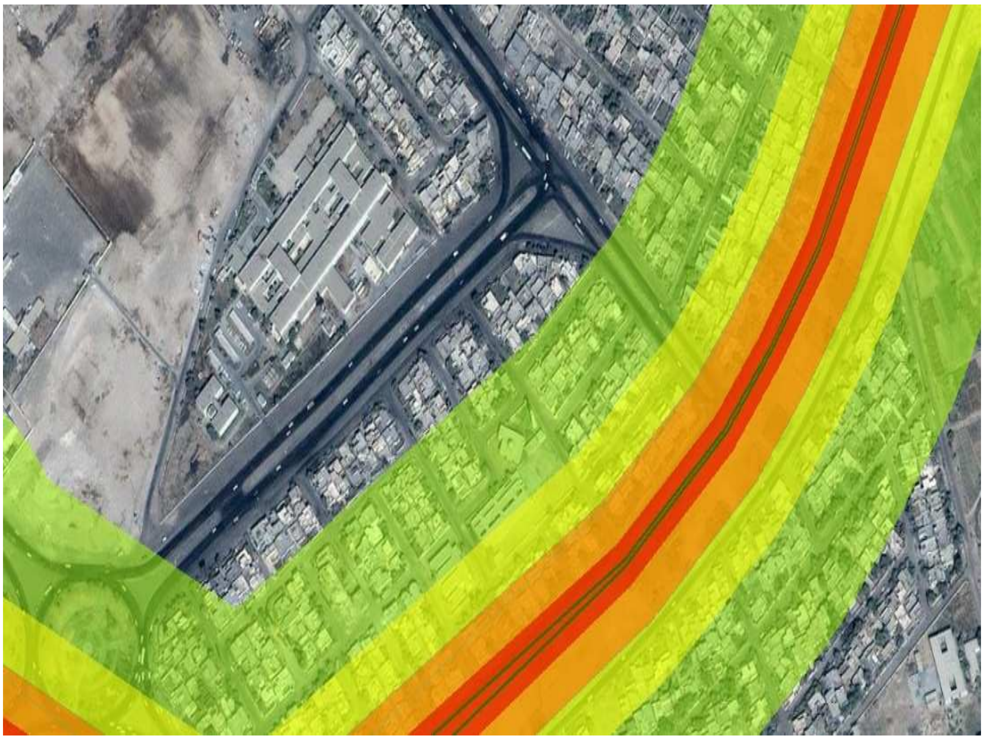

Figure (8) The Magnetic Zones in Alsder City

Figure (9) The Magnetic Zones in Aldora

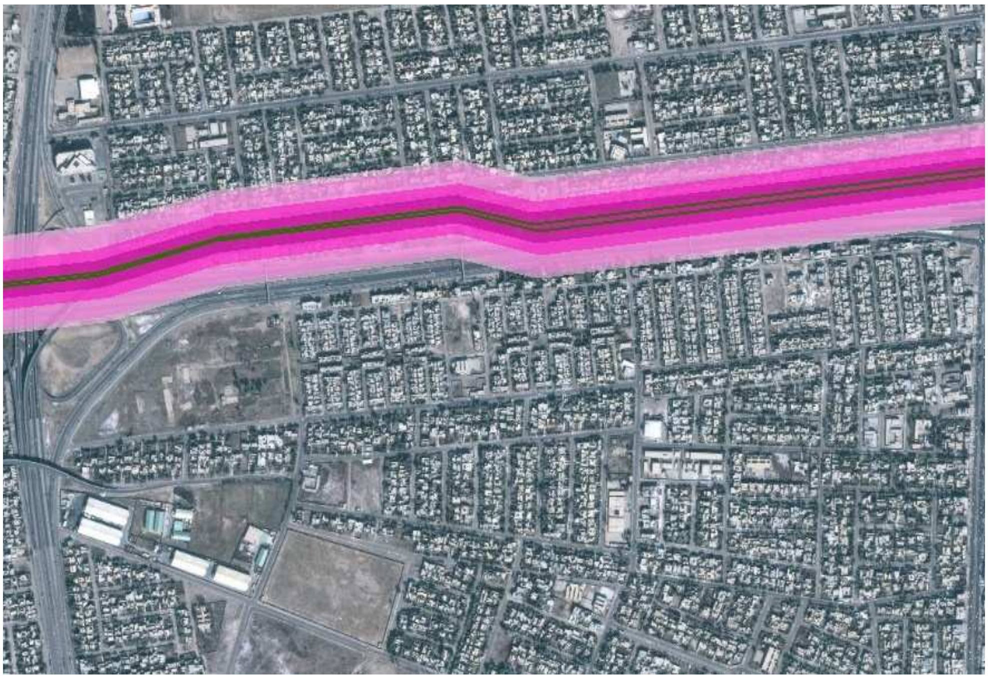

Figure (10) The Electrical Zones in Al Kadmiah District

Figure (11) the Electric Zones in Alkarkh Side of Baghdad