

POWER MAGNETIC FIELDS EXPOSURE EVALUATION AT NORTH LEBANON: GIS APPLICATION

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ABSTRACT

The effects of continuous human exposure to power frequency electromagnetic field (EMF) have been brought to attention due to its possible health hazards. An important source of the EMF is the power frequency high voltage transmission lines when passing near or among residential areas.

In this paper, the creation of an EMF atlas for populated urban areas in North Lebanon traversed by double circuited 66 KV power transmission lines is of focus. For this purpose, environmental conditions or EMF exposure level were measured and simulated around these lines in order to be analyzed and mapped using GIS. The GIS map highlights visually the unsafe zones and will facilitate the extraction of the EMF level of exposure for any non-expert GIS user at any point of interest

I. INTRODUCTION

With the current technological advances in transmitting electrical power, nowadays, the resulted power frequency magnetic fields are receiving more interest to the public because of their probable health effects on human [1].

In this respect, the technological advances have covered the magnetic field instrumentation for accurate measurement and advanced modeling for computer simulation [2],[3]. The three-axial SYPRIS[®] magnetic field meter was used for EMF measurement.

The EPRI RESICALC[®] software developed by Enertech, USA for EPRI was used to model and simulate the cases where residential areas are in the proximity of HV transmission lines.

This paper presents the results of measurements and simulations of power frequency magnetic field on a 66 KV transmission line passing through a residential area in the north of Lebanon: The Kalamoun town situated about 65 Km to the north of Beirut. Systematic measurements have focused on areas where transmission lines are too close to residences. Figure 1 shows a 2D map of the selected region:



Fig 1: 2D view of Kalamoun

II. TRANSMISSION LINES

Overhead transmission line systems in Lebanon can handle a range from 66 KV to 220 KV with one 400 KV connection to neighboring contry. Each tower in this study consists of two circuits arranged vertically with a shield wire on the top of the tower. Bundled circuits exist only for 220 and 400 KV systems.

Since transmission lines traverse wide areas including residential areas as cities, towns ... it became a source of concern for the general public who are aware of their health effects [1].

One particular case, among others, was detected in the Kalamoun town where the single bundled double circuited 66 KV transmission lines traverse the town as shown in Fig. 2 below:



Fig.2: transmission lines near residential areas

The transmission line tower configuration is mainly of two forms as it appears in figure 2, 3 and 4:

1- The 3x3 configuration.



Fig. 3: The 3x3 configuration

2- The 6x0 configuration.



Fig. 4: the 6x0 configuration

The geometrical data of these towers are shown in figures 5 and 6.

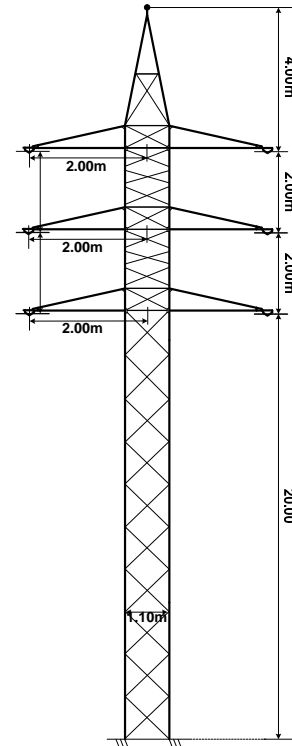


Fig. 5: 3x3 Tower Configuration

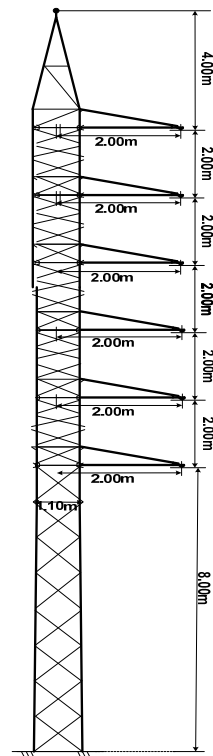


Fig. 6: 6x0 Tower Configuration

In addition to the 66 KV transmission lines mentioned before, the secondary distribution lines or tap lines showed an important additional level on the EMF. A sample of a tap line is shown in Figure. 7-a:



Fig.7-a : Tap lines (220V)

Measurements were divided mainly into two major parts based on the existence of the tap lines with the high voltage (HV) transmission lines.

III. MEASUREMENTS CASES

3.1 HV transmission lines with tap lines

In figures 7-b, 8 and 9, the HV transmission lines are present near tap lines. The HV lines are 66 KV, three phases, double circuited with a shield wire for protection, where tap lines consist of three phases 220 V single circuited line with a ground wire.



Fig. 7-b: Case-1



Fig. 8: Case-2

Notice the new building added in green because it was not appearing on the geographical map.



Fig.9: Case-3 with Tap Lines

3.2 Measurement Procedure

Power loads on the towers and distribution lines were recorded in addition to the time of measurement and the weather status. All these specifications were needed as data input. Measurements were focused mainly under and around towers [4],[5].

IV. THE RESULTS

For clear and observable results, the resulted outputs were presented in different formats: 3D plots, contour and profile plots. In addition to the listed outputs provided by RESICALC, ENVIRO offers also the noise output as a plot

resulted from noisy sounds that transmission lines produce due to corona effects depending on the weather status.

Other areas were treated in the same manner and similar plots were obtained. The results can be arranged in terms of the output EMF values and tabulated as shown below to improve the observations.

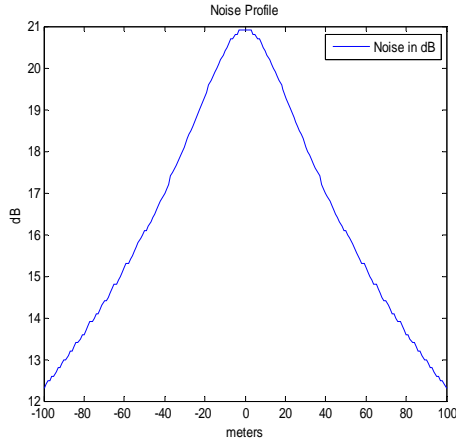


Fig.10: noise profile of area 1 in figure 7-b for a foggy weather.

From figure 10, the noise reaches about 21 dB just under the lines for a lateral profile away 100 meters in each side from the center of the lines. The microphone receiver is located at 1.2 meters above ground.

For each case, many simulation areas and profiles were conducted to produce a true EMF level at different heights and at different loads. Sample measurements were also performed and compared to calculated values to prove the accuracy of the work. Starting from case 1 where towers are about 4 to 5 meters away from power lines and towers, it was modeled as follows:



Fig. 11: Original View of Case 1

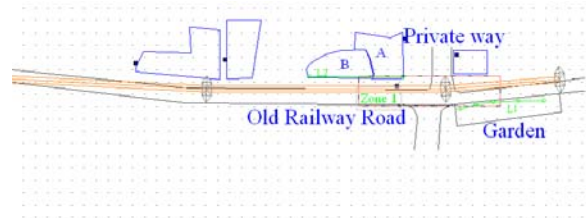


Fig. 12: The RESICALC Model of Case A for the Reference Zone 1

Simulating at a height of 1 meter and with a normal load of 100 Amps for Zone 1 indicated in figure 12 led to the following result:

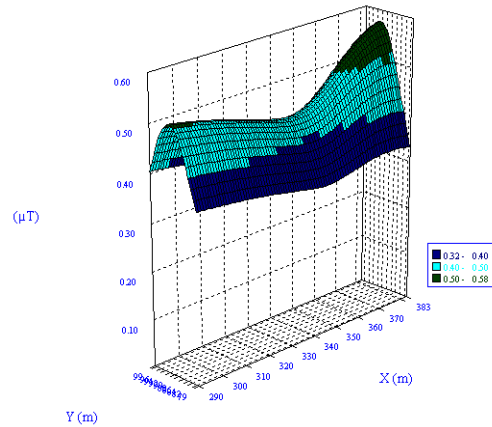


Fig. 13-a: Simulation Results of Zone 1 at 1 Meter Height, 100 Amps Load

At 1 meter height with a normal load of 100 Amps, the magnetic field ranges between 3.2 and 5.8 mG (1μT = 10 mG). These results were for no reversal sequence of phases, i.e., the phases were arranged on each side of the tower from the top to the bottom as ABC – ABC. At maximum load of 320 Amps on the line, the result was the following:

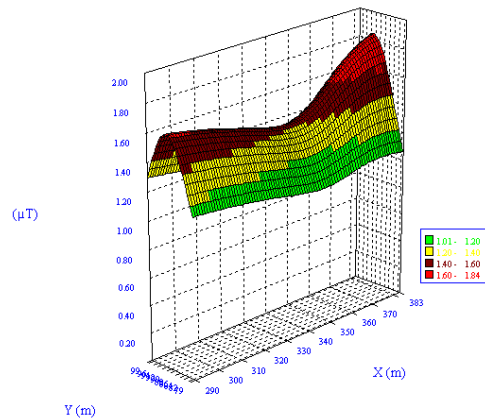


Fig. 13-b: Simulation Results of Zone 1 at 1 Meter Height, 320 Amps Load

The values reached about 18.4 mG with a remarkable increase from 10.1 as a minimum level. Reversing the phases of the circuit leads also to an important decrease in the EMF values since the EMF generated by each phase will be opposing to each other. The following plot illustrates the simulation at 1 meter height, maximum load of 320 Amps but with phase reversal of ABC – CBA sequence. The stated sequence was found to produce lowest magnetic field among other possible sequences.

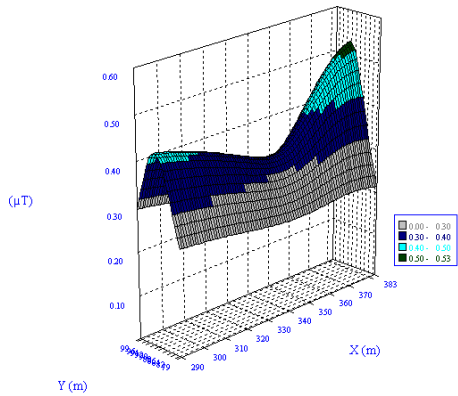


Fig. 14: Simulation Results of Zone 1 at 1 Meter Height, 320 Amps Load with Phase Reversal

Note how the values are decreased from 18.4 to 5.3 mG. Since the majority of the buildings of the Kalamoun town were between 10 and 20 meters, simulating at different heights was quite important to yield EMF values at higher stages of residences near transmission lines. The following plot illustrates this concept for the same Zone 1 taken above for maximum load without phase reversal at 10 meter height:

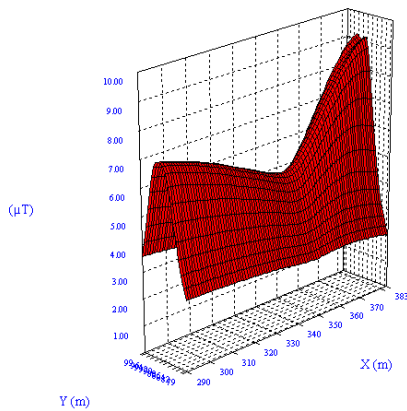


Fig. 15: Simulation Results of Zone 1 at 10 meter height, 320 Amps Load without Phase Reversal

Note how much dangerous the situation is. The numbers reached a value of 90 mG. This value is also near to the houses A and B. Reversing the sequence of the phases from ABC – ABC to ABC – CBA led to reduced values but still dangerous and not safe. This can lead to Leukemia hazards as stated in [1].

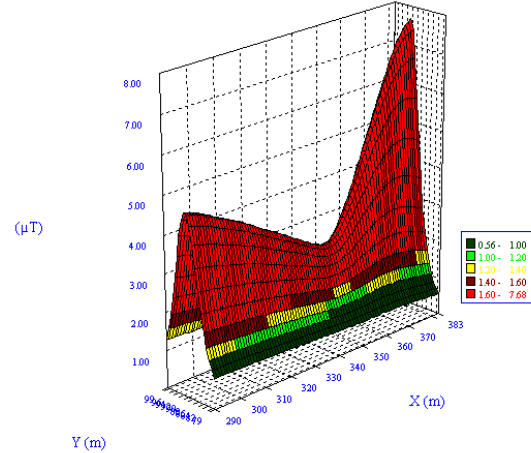
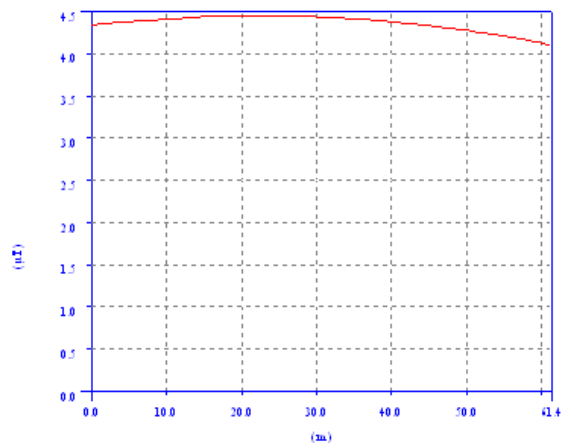
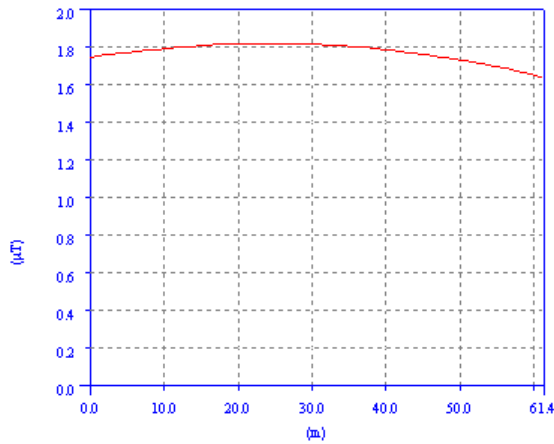


Fig. 16: Simulation Results of Zone 1 at 10 meter height, 320 Amps Load with Phase Reversal

This means that, taking a profile at the balcony of apartments A & B for the same conditions above; at 10 m height, 320 Amps without and with Phase reversal led to the following result. Notice the values have well decreased from about 45 mG to about 18 mG but the 18 mG still be a very high exposure level of EMF.



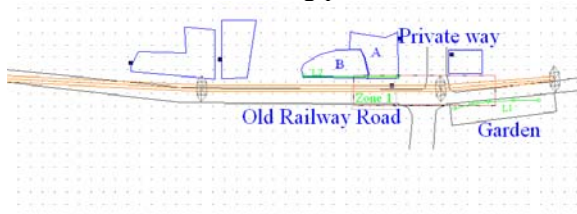
(a) Simulation at 10 Meters Height for 320 Amps Without Phase Reversal



(b) Simulation at 10 Meters Height for 320 Amps With Phase Reversal

Fig. 17: Simulation Results of Zone 1 at 10 Meter Height, 320 Amps Load with Phase Reversal

In a way to give sincerity to the simulations, measurements were acquired and compared to simulations. The following model illustrates the profile of measurement in Case A named L1. Then measurements and simulation results were performed for only one circuit out of two energized at 233 Amps and the results were overlaid and the following plot was obtained:



(a) The Selected Profile L1

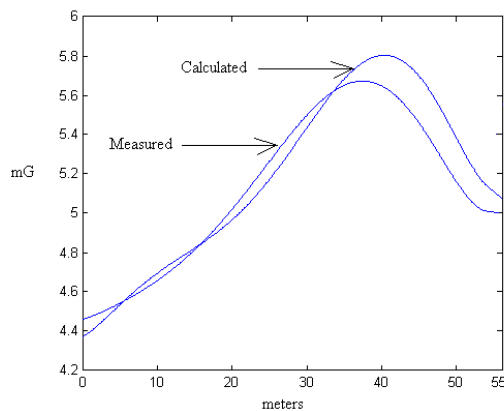


Fig. 18: Calculated vs Measured EMF for L1

Note that the error range falls into the 5% error which validates the modeled cases.

The second case, Case 2, was also of quite importance since the lines pass mainly near the residences with a maximum separation distance of 6 meters between them. Power lines are of the 6x0 fashion, this means that the lowest phase conductor is not high enough, about 13 meters in a residential area with the height of the many houses is more than 13 meters as figure 9 shows ; the last floor of the house is found directly opposite the lowest conductor. So, simulating at different heights will clarify better the situation. In additions to the high voltage transmission lines, tap lines are also present which made the situation even worse since tap lines can handle about 700 Amps and so forth they had an important impact on the level of EMF.

The following figure shows the simulation area, Zone 1, which includes the tap lines to show their effect.



Fig. 19: Zone 1 of Case 2 of Kalamoun Showing the Tap Lines

Simulation was performed at a height of 1 meter, with a normal load of 100 Amps without phase reversal and the following results were obtained.

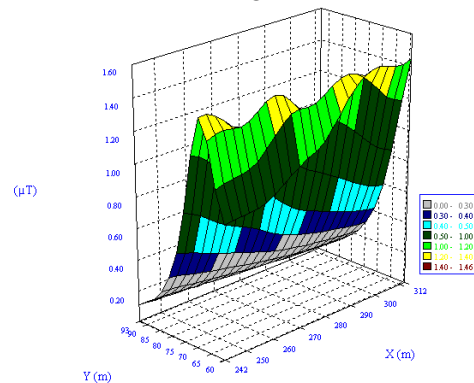


Fig. 20: Simulation Results of Zone 1 at 1 Meter Height, 100 Amps Without Reversal

Notice that higher values of EMF are located to the side of the lower conductors of high voltage towers, i.e. to the side of the road. So, at 1 meter, a habitat is exposed to about 10 to 20 mG which can be considered as a dangerous situation. The levels can be reduced by reversing the phases as the following plot shows, keeping the same conditions of 1 meter height, 100 Amps load but with phase reversal.

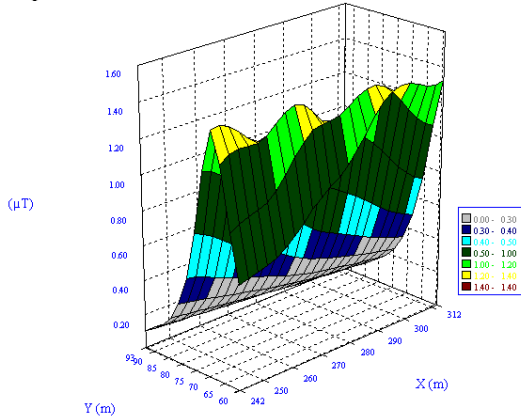


Fig. 21: Simulation Results of Zone 1 at 1 Meter Height, 100 Amps but with Reversal

Notice that the maximum values have diminished to 14.6 mG which is relatively a high EMF level for 24 Hours exposure. The case should be investigated at maximum load also to show all aspects of the EMF levels at all possible heights. For the same Zone 1 selected before, simulating at 1 meter height with the maximum permissible load of 320 Amps, even with reversing the phases, the following plot is obtained:

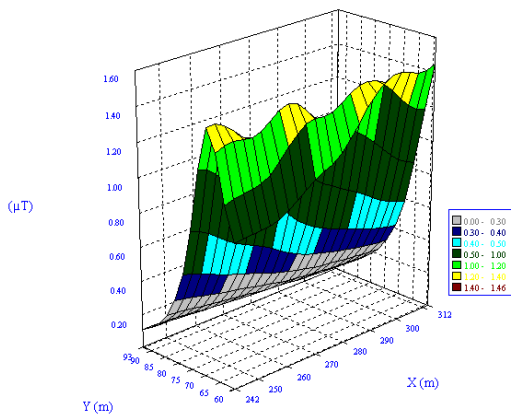
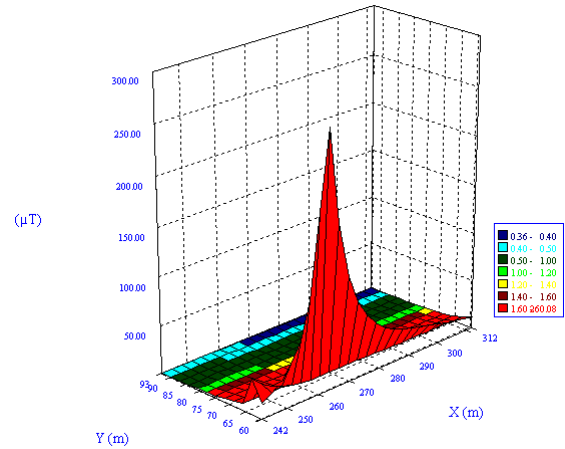


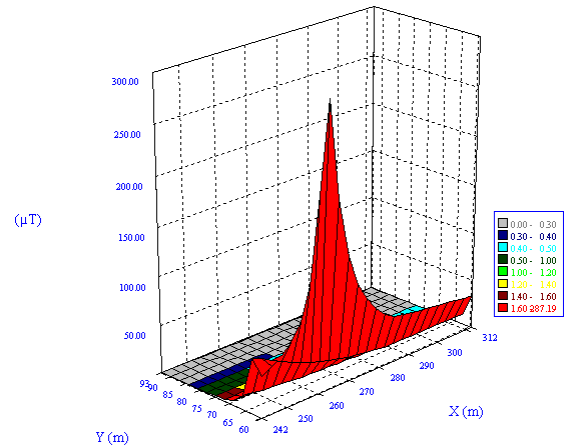
Fig. 22: Simulation Results of Zone 1 at 1 Meter Height, 320 Amps but with Reversal

The EMF levels reached 14.6 mG which is found between the houses and the towers. At higher heights, the situation is even worse, as mentioned above. So, simulating at 17 meters, at the roof of the building, at the maximum load and with and without reversal conditions led to the following results.



(a) Results at 17 meter, 320 Amps without Reversal

Very high peaks as the 260 μ T are encountered on the conductors or very near to them. This happens because of the height where simulations were performed.



(b) Results at 17 meter, 320 Amps with Reversal
Fig. 23: EMF Levels of Zone 1 at Different Loads

The following plot shows the calculated EMF level at 1 meter high, for 320 Amps load without phase reversal.

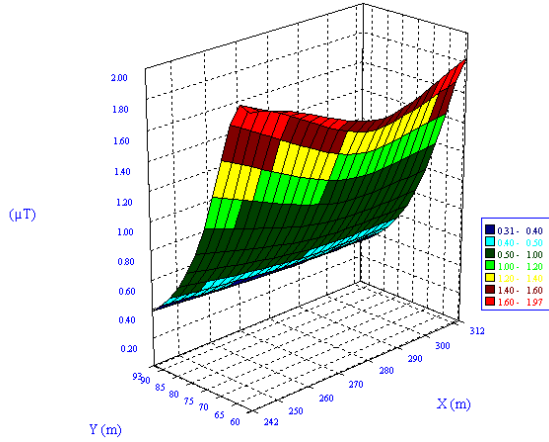


Fig. 24: EMF levels of Zone 1 at Maximum Load with No Reversal but Tap Lines Removed

Notice that at the worst case scenario, 320 Amps load without phase reversal, simulating at 1 meter height led to a maximum value of 19.7 mG. Reversing the phases led to lower EMF levels as shown through the figure below.

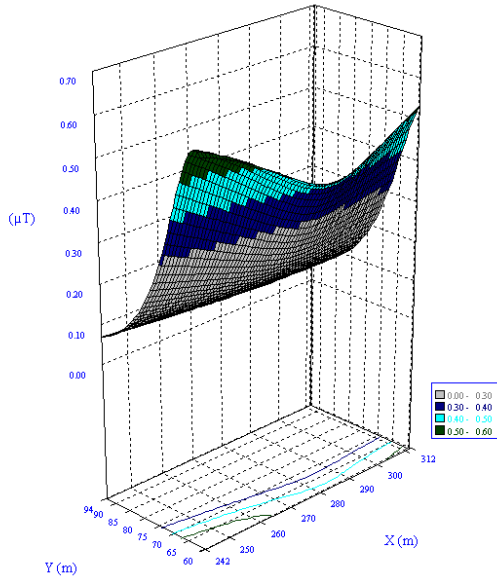


Fig. 25: EMF levels of Zone 1 at Maximum Load with Reversal but Tap Lines Removed

One can see clearly by how much the EMF level is decreased. The third case, Case 3, reflects similar conditions faced in Case 1 where the power lines are too close to residences, about 3 to 6 meters separation distance between them. For illustration, the Zone 1 was selected to reflect the EMF levels encountered in this case. Simulation was performed at 1 meter high, for a

normal load of 100 Amps without phase reversal and the following figure was obtained.

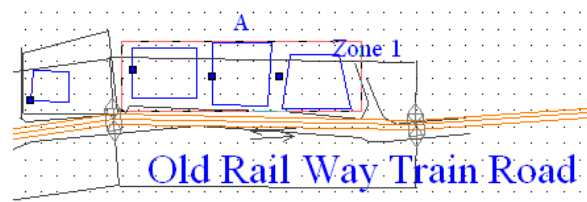


Fig. 26: Selected Zone 1 of Case 2 of Kalamoun

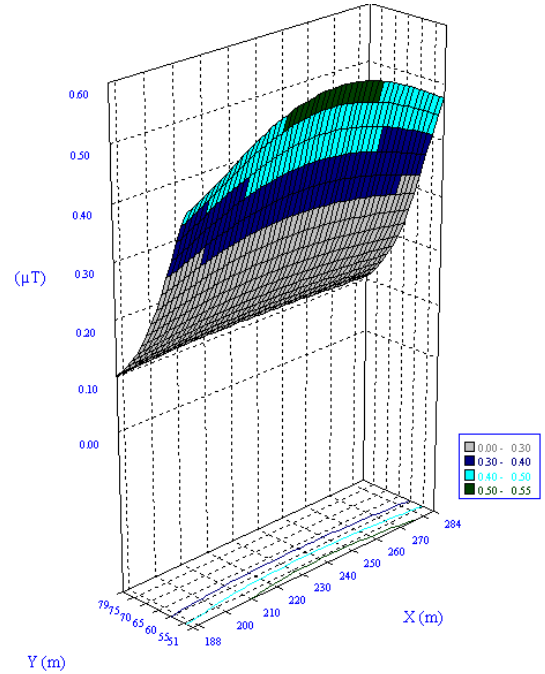


Fig. 27: Simulation Results for Zone 1 at 1 Meter Height, 100 Amps Load Without Reversal

The situation tends to be worse when going up with the load and the height of calculation. So simulating at 15 meters with a load of 320 Amps without phase reversal led to the following plot.

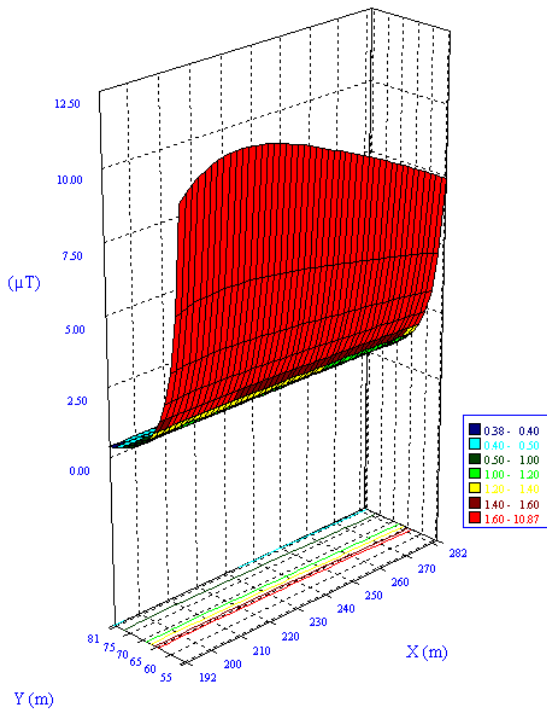


Fig. 28: Simulation Results for Zone 1 at 15 Meter Height, 320 Amps Load Without Reversal

By collecting the previous results, an ATLAS is prepared showing the EMF level for the whole town for different loads and heights. For the Kalamoun, the remaining areas were modeled in RESICALC to complete the model of the Kalamoun town. The following figure shows some important EMF Atlas Maps.

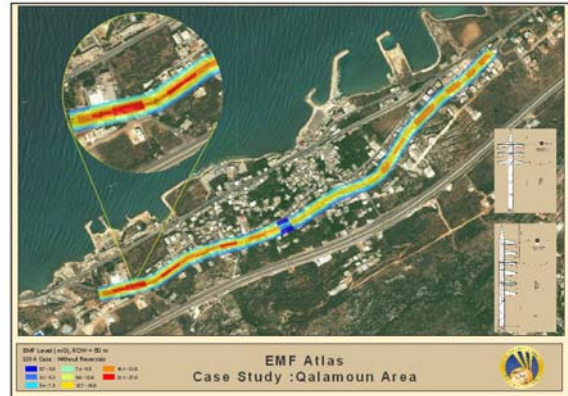
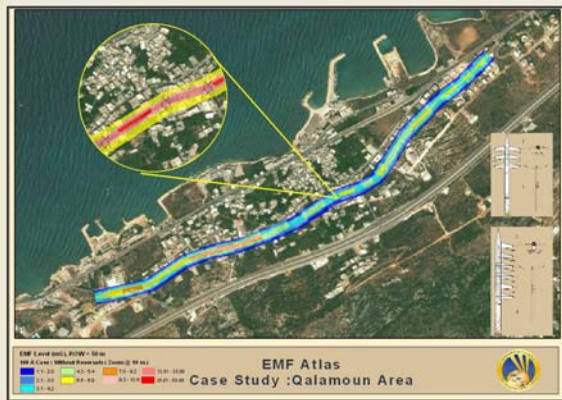


Fig. 29: GIS ATLAS Mapping of EMF levels

V. CONCLUSION

In this paper, the results of power frequency magnetic field measurements on a 66 kV transmission line in existence with a 220 V distribution line were presented. The three-axial SYPRIS[®] magnetic field meter was used for measurement. The proximity of tap lines and HV lines led to remarkable increase in the EMF as shown through plots. Different graphs illustrated the close correspondence between the measured and the calculated EMF values. Multiple output formats, 3D, contour and profile plots, were provided for more observations. Noise study was also covered to emphasize the “audible pollution” resulted from HV lines in addition to possible health risks caused by EMF.

VI. ACKNOWLEDGMENT

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VII. REFERENCES

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