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MAGNETIC FIELD MEASUREMENTS UNDER TWO-POLE TYPE DISTRIBUTION SUBSTATIONS IN THE LOW FREQUENCY RANGE

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ABSTRACT
Taking into consideration that generation, transmission and distribution of electric power are accompanied with the presence of magnetic and electric fields, it is not surprising that the concern of the public regarding the possible effects from the exposure to the above mentioned fields has grown considerably the last decades. This paper intends to demonstrate the values of the resultant magnetic field, deriving from low frequency magnetic fields, that can be recorded in residential areas close to two-pole type distribution substations 20/0.4kV. The measurements were conducted in three representative regions based on the density of the existing buildings. It became evident that the magnetic field values were lower in comparison to the international specified limits.

KEY WORDS
Magnetic field, measurements, two-pole type distribution substation, low frequency, residential area.

1. Introduction

Electrical energy is an essential element of human activity. Due to the vast extend of its networks it is integrated in almost all aspects of human life.
The frequencies of 50 or 60Hz, from the early beginning of electricity have been chosen for technical and economical reasons. The generation, delivery and transfer of energy are associated with the presence of magnetic and electric fields.
Over the last three decades the concern for the possible affects from the exposure to low frequency magnetic fields to the public has been impressively increased. Many epidemiological studies suggest that human exposure to such fields correlate to many types of cancer. [1-3].
Based on guidelines introduced by international organizations like ICNIRP (International Commission on Non- Ionizing Radiation Protection) and CENELEC (Comité Européen de Normalisation Electrotechnique) [4-5] has led many countries to adopt limits to the recommended maximum exposure of the general public.
According to ICNIRP guidelines the limits of the exposure from low frequency magnetic fields are 100μT (1000mG) for general public and 500μT (5000mG) for occupational exposure. These limits are taken in consideration during the design and construction process of power networks.
According to our knowledge, past studies were mainly targeted on measurements and simulations of magnetic field of outdoor power substations 230kV and 150/20kV [6-7] and indoor distribution substations 20-0.4 kV [8-9].
In this work, measurements of industrial frequency magnetic field under two-pole type distribution substations 20/0.4 kV, in residential areas were performed. These kind of substations are commonly used in the Greek distribution network. A comparison of the magnetic field values measured and those specified as limits was also made.

2. Magnetic field measurements

The measurements took place in three different regions of Athens. The first set was carried out in an area with a medium concentration of buildings (region A). The second in a suburb outside Athens which is under populated with small houses and villas (region B) and the third set was in a neighborhood near the city center where the density of building is very high (region C).
The instrument that was used to measure the resultant magnetic field was the EMDEX II of Enertech Consultants, with frequency range 40-800 Hz.
The measurements were conducted according to IEEE Standard 644-1994 [10] in three different heights 1.5m, 1.7m and 1.9m above the ground (trying to estimate the position of the heart and brain of an average human) and in three distances 0m,2m,3m from the center of the Low Voltage switchgear (see figure 1).
Figure 1 demonstrates a typical configuration of the two-pole type distribution substations 20/0.4 kV, supported by wooden or concrete poles according to the time period that they were build. Our study was focused on two types of substations with nominal power of the installed transformers 250 KVA and 400 KVA.

Figure 1. Typical configuration of a two-pole type distribution substation. 1:Medium Voltage Line, 2:Fuse Disconnectors, 3: Low Voltage Line, 4:Transformer, 5: Low Voltage switchgear.

Table 1. Resultant Magnetic field (μT) in Area A.

Substation	Height (m) / Distance (m)	1.5	1.7	1.9
		Resultant Magnetic Field (μT)		
1	0.0	43.20	23.55	14.55
	1.0	4.90	4.90	4.95
	2.0	2.60	2.90	3.25
2	0.0	46.95	41.85	33.85
	1.0	5.35	5.80	5.40
	2.0	2.15	2.05	1.85
3	0.0	25.15	15.20	9.35
	1.0	6.70	5.50	5.45
	2.0	4.40	3.75	3.70
4	0.0	60.2	34.95	28.60
	1.0	9.75	9.70	10.50
	2.0	5.55	5.30	6.30
5	0.0	9.85	11.35	2.45
	1.0	2.10	2.55	2.15
	2.0	1.20	1.50	1.50
6	0.0	34.80	19.10	11.75
	1.0	4.85	4.95	4.95
	2.0	0.090	1.20	1.20
7	0.0	21.60	14.50	11.40
	1.0	11.65	10.30	8.80
	2.0	4.00	3.75	3.70

The poles height and the position of the transformer are approximately 10m and 6m above the ground.

Table 2. Resultant Magnetic field (μT) in Area B.

Substation	Height (m) / Distance (m)	1.5	1.7	1.9
		Resultant Magnetic Field (μT)		
1	0.0	63.20	38.40	10.05
	1.0	34.00	3.05	2.90
	2.0	1.50	1.90	1.50
2	0.0	11.75	4.70	2.20
	1.0	2.05	2.45	2.15
	2.0	1.20	1.25	0.90
3	0.0	61.10	56.80	26.40
	1.0	3.80	4.25	3.65
	2.0	2.20	2.10	2.10
4	0.0	4.25	1.90	1.40
	1.0	1.20	1.00	1.00
	2.0	0.55	0.40	0.00
5	0.0	64.60	54.40	10.60
	1.0	3.20	3.10	2.85
	2.0	1.00	1.00	0.70
6	0.0	17.80	10.30	7.75
	1.0	3.70	3.55	3.50
	2.0	1.80	1.50	2.15
7	0.0	8.50	7.00	4.55
	1.0	4.65	4.70	5.00
	2.0	3.25	3.50	3.45

This experimental study is focused on residential areas during winter time. The main criterion for choosing our magnetic field measurements to be conducted, on Friday evening and Sunday mid morning, was the satisfactory levels of electrical energy consumption. This is due to the fact that a large number of people are in their homes; therefore the level of load of the substations transformers will have reached a satisfying degree

In region A where the concentration of buildings is medium, the measurements where carried out on Friday 20.02.2009 between 17:00-19:00. The atmospheric conditions during the experimental study were: temperature between 8.4 - 9.0 °C and relative humidity 38.9-41.9%. In the other two areas B- scarcely populated- and C - near the city center- the measurements were conducted on Sunday 22.02.2009 and 22.03.2009 between 09:00-12:00. For area B the temperature and the relative humidity variation was between 5.0 - 6.9 °C and 47.8-50% and for area C the temperature and the relative humidity variation was between 10.0 - 12.9 °C and 35.8-38.0% respectively.

The data presented in the tables 1 to 3 are the measurements of the resultant magnetic field in μT for seven two-pole type distribution substations in region A, B and C respectively.

Table 3. Resultant Magnetic field (μT) in Area C.

Substation	Height (m) / Distance (m)	1.5	1.7	1.9
		Resultant Magnetic Field (μT)		
1	0.0	49.95	33.60	51.20
	1.0	10.00	10.00	7.00
	2.0	0.00	0.00	0.00
2	0.0	44.40	28.60	8.70
	1.0	3.20	3.05	3.00
	2.0	1.90	1.65	1.65
3	0.0	65.60	53.60	8.80
	1.0	7.15	6.90	6.16
	2.0	2.10	2.10	1.65
4	0.0	61.60	42.40	40.80
	1.0	10.75	8.05	7.50
	2.0	5.50	4.95	4.70
5	0.0	92.00	60.00	28.15
	1.0	3.15	3.15	2.80
	2.0	1.50	1.50	1.50
6	0.0	70.40	48.80	17.60
	1.0	23.50	2.15	1.75
	2.0	0.70	0.70	0.55
7	0.0	82.40	64.00	56.80
	1.0	3.45	4.10	3.45
	2.0	0.55	0.55	0.55

3. Discussion

From the analysis of the experimental data, we can conclude that in all studied heights and distances the measured field values were lower in comparison to the international specified limits.

In contrast to previous studies [8-9] regarding indoor substations 20/0.4kV we can discern that the conducted measurements of magnetic field in the two pole type substations were lower. This differentiation was identified because the measurements were taken in a longer distance from the transformer and the field decays as the distance increases.

It can be pointed out that the nominal transformers power of our study was 250 and 400 KVA whilst in previous works [8-9] was bigger.

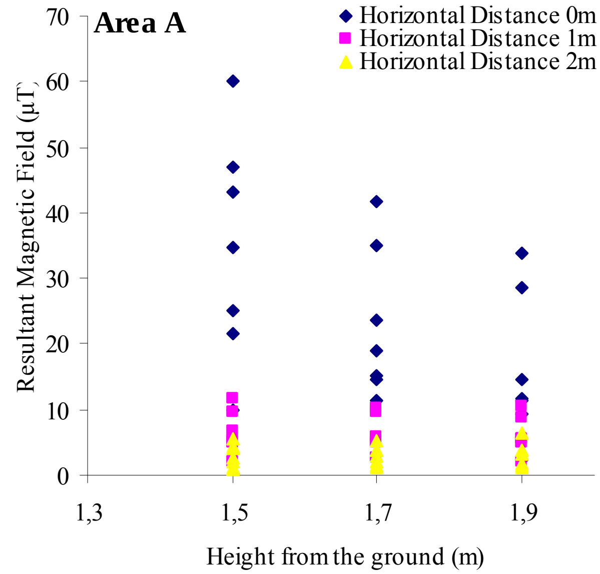

Figure 2. Magnetic field distribution in substations in Area A.

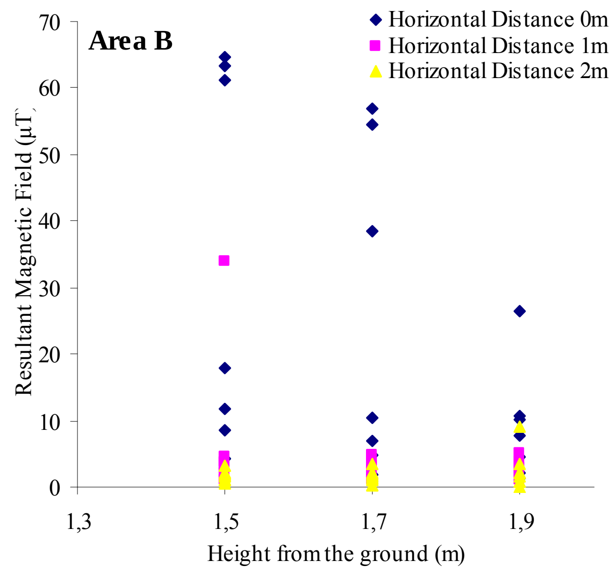

Figure 3. Magnetic field distribution in substations in Area B.

The figures 2, 3 and 4 give us a better perspective of the dispersion of the magnetic field values. It is interesting to note that the higher values of the magnetic field density was experienced in the minimum horizontal distance, from the LV switchgear of the substation and at a height of 1.5m from the ground in all areas. The values in 0m are considerably higher in comparison with the other distances in all three studied heights; this is due to the fact that the measurement was conducted near the LV switchgear. These higher values can be attributed to the influence of the currents in the LV switchgear of the substation.

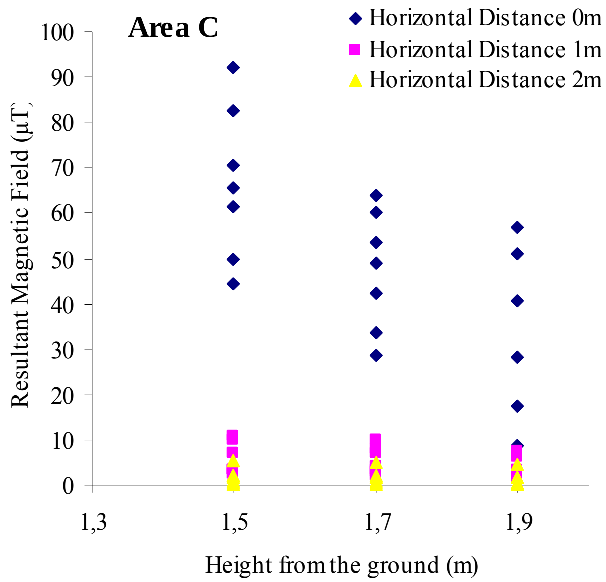

Figure 4. Magnetic field distribution in substations in Area C

It can be pointed out that the magnetic field, decays in a very high rate as the horizontal distance from the substation increases. As a result the values that have been witnessed at 2m are significantly lower.

Fig.2 displays that the dispersion between the maximum and minimum values is 59.30μT of the measured values in distance 0m, whereas the dispersion between the rest of the values is relatively closer.

In Fig.3 it is revealed that two different levels of charge of the transformers of the substations exist. This can be due to the fact that the region is under populated and the locations of some of the substations were near the existing houses and some in a considerable distance. In this area we have witnessed numerous amounts of the lowest measured values of the field.

Fig.4 shows that the measured values in the region near the city center are the highest with the smallest dispersion.

4. Conclusion

As a conclusion we can say based on the measurements, of the low frequency magnetic field, under two-pole type distribution substations 20/0.4 kV of nominal power 250 and 400KVA and analysis of the experimental data that followed, that the values of the resultant magnetic field varied between 0.00 and 92.00μT, which are lower in comparison to the values proposed by the international guidelines. In distances of 1 and 2m the values of the field were low, while the highest values were found in the minimum horizontal distance from the LV switchgear as expected.

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