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Investigate and Analyze the Electromagnetic Field Levels Inside an Electric Power Substation

Kamil Jadu Ali *

Ghanim Thiab Hasan

Mahmood Ali Ahmed

Electrical Engineering Department
Tikrit University
Salahuddin
Iraq

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ABSTRACT

The electric power transformers are very important part of the modern electric power and transmission line network systems. They are a high level source of the electromagnetic fields which can effect the workers health in the station. In this research, an electric and magnetic fields are generated due to the operation of the substation power distribution of 132/33 kV that investigated in order to avoid the workers overexposure these fields workers. This research has two phases a mathematical calculations and practical measurements. The intensities of the electric and magnetic fields have been measured at a substation using EMF tester device. The safe zones around the dangerous equipment have been determined. A comparison between the obtained results and the standard safety guideline limits has been done and the comparison results shows that they are within the acceptable limits.

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حساب وتحليل شدة المجالات الكهرومغناطيسية داخل محطه فرعيه لتوزيع الطاقة الكهربائية

الخلاصة

تعتبر المحولات الكهربائية العنصر الاساسي في شبكة نقل وتوزيع الطاقة الكهربائية لذا فهي تعتبر مصدر لانبعاث الاشعاعات الكهرومغناطيسية والتي يمكن ان تؤثر على صحة العاملين في محطات التحويل. تم في هذا البحث قياس مستويات المجالات الكهربائية والمغناطيسية الناجمة عن تشغيل محطات توزيع الطاقة الكهربائية 33/ 132 كيلو فولت كما تم تحديد المسافات الأمنه من بعض الأجهزة بهدف تجنب التعرض المستمر لهذه الاشعاعات من قبل العاملين. تم اجراء القياسات بطريقتين: الحسابات الرياضية والقياسات العملية. مقارنة النتائج الحاصلة مع الحدود الأمنه المسموح بها دوليا المحدد من قبل منظمة الصحة العالمية تبين عدم وجود مخاطر على صحة العاملين في تلك المحطات اذا كان التعرض لفترات قصيره ومتقطعة.

1. INTRODUCTION

Every day, we get exposed to electromagnetic fields from different sources of electric and magnetic fields (EMF) that emitted from power lines, transformers, wires, and home appliances [1]. The main purpose of the substation is to transform voltage to a more appropriate level. So, all electrical structures may cause electromagnetic fields such as switching equipment, feeding lines, VAR compensation and power cables [2]. Many researchers have emphasized studying and investigating the effects of EMF on the human health that associated with the electromagnetic fields. And this cause many health troubles such as epilepsy, cancer, brain tumors, and disorders [3].

EMFs are lines of force that surround the electrical wires or devices. These fields are considered as time-varying quantities which are characterized by some parameters, such as frequency, phase and magnitude. Electric and magnetic fields become weaker with distance increase between the person and the source. Electric fields can be easily weakened by objects such as buildings, trees or human skin. Magnetic fields, on the other hand, could be not weakened because of their ability to pass through anything which doesn't contain high concentrations of iron [4].

* *Corresponding author: E-mail* : kamil.ali77@yahoo.com

Some organizations have been established and set some guidelines for limiting the EMF exposure to avoid adverse health effect. The (ICNIR) established in 1998 and issued its guidelines exposure limits. Table 1 illustrates the limit levels of the electromagnetic field exposure set by WHO to be taken into account when evaluating an electromagnetic field levels in working places [5].

Table 1
Exposure limits for the electromagnetic fields.

(EMF)	E (V/m)	B (µT)
Occupational	10KV/m	500 µT
General public	5 K V / m	100 µT

2. LITERATURE REVIEW

For estimating the electromagnetic fields intensity, in the following paragraph a brief is presently of some studies about the biological effects of the electric and magnetic fields.

1- Feychting, Verkasallo et al (1993), Tynes (1997) conducted some calculations based methods. The early studies indicated that an increase of the EMF danger cause diseases especially in children who are living in an industrial cities and are directly exposed to high voltage power lines. Due to bad housing safety conditions, EMF becomes a social challenging health problem [6].
2- Reilly conducted a study in 1978 on a sample of 122 persons who stand directly near overhead transmission lines under various conditions; 90% of them could perceive a 20 kV/m 60 Hz electric field, and perception reached a self-reported ‘annoyance’ threshold of 10%. A small percentage of reported that perception at field strengths was below 5kV/m [7].
3- Graham in his study of the electric fields (0–15kV/m) and magnetic fields (0–40mT) used a sample of 10 men and 10 women aged (21–35). The threshold of 90% of the group was 39kV/m. The study showed that perception was improved when the field onset was abrupt and when the volunteer changed his\her position under the effect of field. Moreover, it showed that perception of field onset ceased after about 20 min of exposure but was immediately reestablished by human movements within the field [8].

3. METHODOLOGY

Measurements of the magnetic and electric field levels are performed in following steps:

1- Mathematical calculations.
2- Practical measurement.
3- Determining the safe and unsafe ranges for some power equipment that are in attachment with the workers in the power substation. An investigation of the electric and magnetic fields in the substation has been performed in two steps:

3.1. Mathematical Calculations

The calculation of the magnetic fields of the straight wires is conducted using the Biot-Savart law [9]. If an infinite straight conductor, is in the z-axis direction and carrying a current I as shown in Fig. 1.

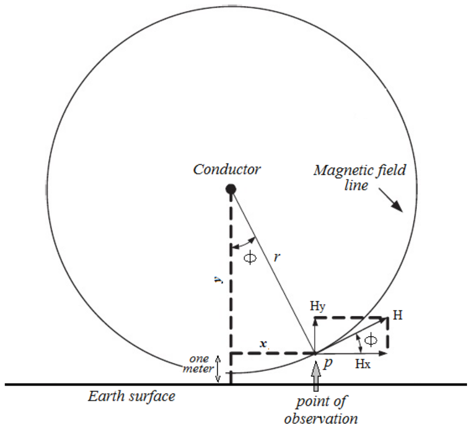

Fig. 1. Geometry is used to calculate the magnetic field at the point p (x , y) due to the phase conductor.

The distance between the small segment dl and the point is r, then the magnetic field that contributed by each individual segment dl at point P will give the following:

$$B_\theta = \frac{\mu_o}{4\pi}\int_{-\pi/2}^{\pi/2} \frac{I\,\rho}{\rho^3(\cos\phi)^{-3}}\frac{\rho}{\cos^2\phi}d\phi = \frac{\mu_o\,I}{4\pi}\int_{-\pi/2}^{\pi/2}\cos\phi\,d\phi = \frac{\mu_o\,I}{4\pi}[\sin\phi\,]_{-\pi/2}^{\pi/2} \quad (1)$$

$$\left.\begin{aligned} I\times(r-r') &= I\,\rho\,\hat{\theta} \\ dl &= \frac{\rho}{\cos^2\phi}d\phi \\ |r-r'| &= \frac{\rho}{\cos\phi} \end{aligned}\right\} \quad (2)$$

$$B(r) = \frac{\mu_o}{4\pi}\int \frac{j(r')\times(r-r')}{|r-r'|^3}d^3r' \quad (3)$$

$$E(r) = \frac{1}{4\pi\epsilon_0}\int \rho(r')\frac{r-r'}{|r-r'|^3}d^3r' \quad (4)$$

The present calculations for the electric and magnetic fields of (132/33 kV) include all the electrical power equipment and their connections in the substation, as follows: 132 kV switchyard, transformers and kV switchyard. Table 2 illustrates the currents values of all elements that effect the electric and magnetic fields levels which will be considered for the measurement of the electric and magnetic field levels of 132/33 kV substation.

Table 2
currents values.

Equipment	Current (Ampere)
132 kV cable box	400
132 kV transformer box	210
Primary winding transformer	210
Secondary winding transformer	1155
33 kV transformer switchgear	1155
33 kV switchgear	150

3.2. Practical Measurements

These measurements were conducted on a 2m×2m grid at a one-meter height above the substation floor level as illustrated in Fig. 2.

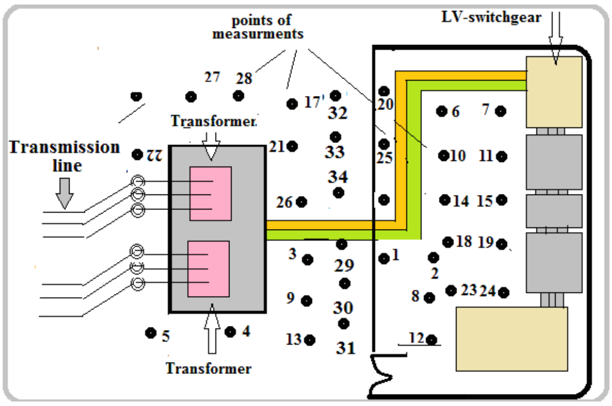

Fig. 2. Measurement points in the substation.

Electric and magnetic fields measurements are conducted using EMF tester (PMM 8053).

4. RESULTS AND DISCUSSION

By applying the above equations, a mathematical result has been obtained and presented in Table 3.

Table 3
Mathematical calculation results.

Area	No.	B(μT)	E(V/m)
Near the transformer	1	15.64	795
	2	13.76	687
	3	40.97	5437
	4	51.32	6443
	5	52.32	73
	6	16.74	4
	7	18.78	2374
	8	14.52	2169
	9	43.76	5923
	1	15.91	966
	0	13.84	676
Avg.		29.9	3240

The measured results of the electric and magnetic flux are given in Tables 4 and 5. Average values of the calculated and the measured fields (VALUES) are shown in Table 6.

Table 4
Measured results of the electric and the magnetic fields near by the transformers.

Area	E(V/m)	B (μT)
132 kV switchyard	3665	24.76
Transformers	1176	21.54

In order to know the safe zones for electric field strength (E) and magnetic field density (B) level, of the equipment inside the substation which are in attach (in touch) with workers, (Circuit Breaker, transformer and Control box), the electric and magnetic fields levels have been measured at three ranges as follows: a- At a distance of 0.15m from the source, b- At a distance of 0.4m from the source, and c- At a distance of 0.75m from the source.

Table 5
Measured results of the electric and the magnetic fields near by the LV Switchgear.

Area	Point No.	B(μT)	E (V/m)
Near the LV Switchgear	23	36.40	1490
	14	31.64	13
	15	14.72	8
	16	32.87	796
	17	38.65	1292
	18	31.73	1843
	19	18.89	1132
	20	35.54	987
			1651
Average		24.62	1325

Table 6
Average values of the calculated and measured values or FIELDS.

Area	Point No.	B(μT)	E (V/m)
Near the LV Switchgear	23	36.40	1490
	14	31.64	1398
	15	14.72	796
	16	32.87	1292
	17	38.65	1843
	18	31.73	1132
	19	18.89	987
	20	35.54	1651
Average		24.62	1325

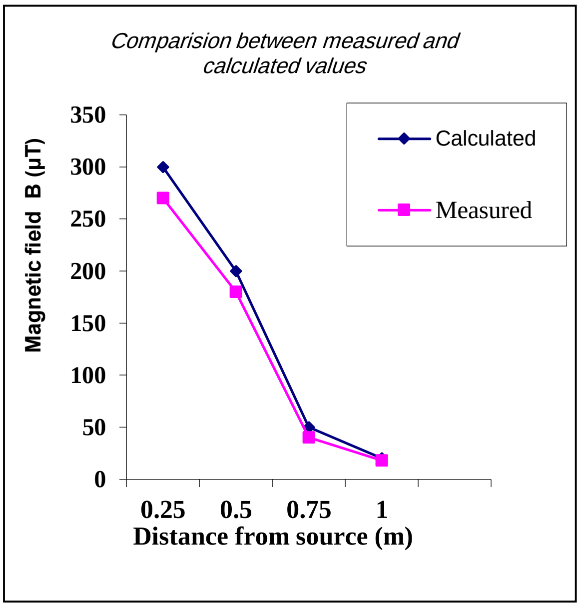

Fig. 3. Comparison between the calculated and the measured values of the magnetic flux density

The measured values for (E) and (B) for the three distances between the points and the sources are shown in Tables 7 and 8 while the graphic at representation for these results are illustrated in Figs. 3 and 4.

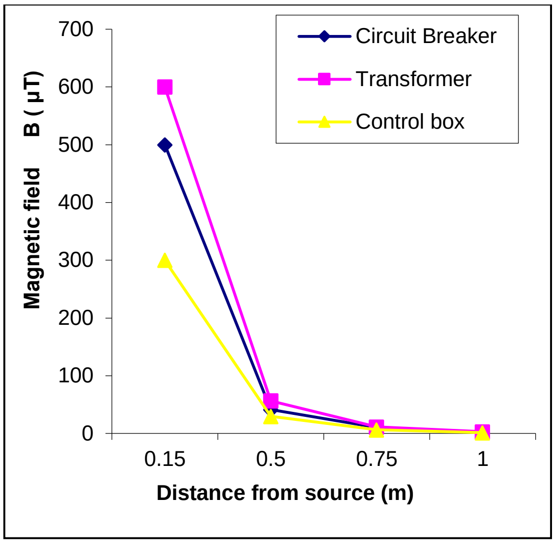

Fig. 4. Graphical representation of the measured results for the magnetic field density (B) for the three distance values.

Table 7
Measured results of (E) at the three positions.

Equipment	E(V/m) (0.1m)	E(V/m) (0.4m)	E(V/m) (0.75m)
Cir. Breaker	11315	4315	1420
transformer	12978	5278	1583
Control box	8575	2575	1127
Control box	8575	2575	1127

Table 8
Measured results of (B) at the three positions.

Equipment	B (μT) (0.15 m)	B (μT) (0.4 m)	B (μT) (0.75m)
Cir. Breaker	542.21	41.21	10.12
transformer	669.6	56.6	11.41
Control box	312.62	29.62	6.36

From this study, the following points may be deduced:

- From Table 6 it could be seen that there is a deviation between the calculated and the measured values in the range approximately (9 % - 12%) in the switchyard and near the transformers. This may be justified that the model does not consider the actual operating data of the plant or not sufficiently detailed.
- Measurements readings are within the standard limits that recommended by the ICNRP;(500μT) and (10kv/m) for occupational exposure as indicated in Table 1.
- From Tables 7 and 8 the safe zones could be located around that EMF source as follows:

Circuit Breaker

a- 0.15 m distance around the (Circuit Breaker), (B=542μT>500μT) and (E=11315 V/m > 10KV/m), is unsafe circular (zone) according to the international exposure limits set (ICNRP) for occupational exposure limits level (B = 500 μT and E= 10KV/m).
b- 0.3 m distance around the (Circuit Breaker) emitting value is (41.21μT<500μT) and (E=4315 V/m <10KV/m), thus it is a safe zone.
c- 0.75 m distance around the (Circuit Breaker) emitting value is (11.41μT<500μT) and (E=1420 V/m < 10kV/m), so also, it is a safe zone.

Transformer

a- 0.15 m distance around the Transformer, reaching is (B=669.6μT>500μT) and (E=12978V/m>10kV/m). It is not a safe range (zone).
b- 0.3 m distance around the Transformer, (B=56.6μT<500μT) and (E=5278V/m<10kV/m), is a safe zone.
c- 0.75 m distance around from the Transformer is a safe zone,(B=11.41μT<500μT) and E=1583V/m<10kV/m.

Control box

a- 0.15 m distance around the Control box, is a safe range zones where the (B=312.62μT<500μT) and (E=8575V/m<10kV/m).
b- 0.3 m distance around from the Control box, (B=29.62μT<500μT) and (E=29.62V/m<10kV/m), is a safe zone.
c- 0.75 m distance around the Control box is a safe zone, (*B*=6.36μT<500μT) and (*E*=1127V/m>10kV/m). And this is illustrated in Fig. 5.

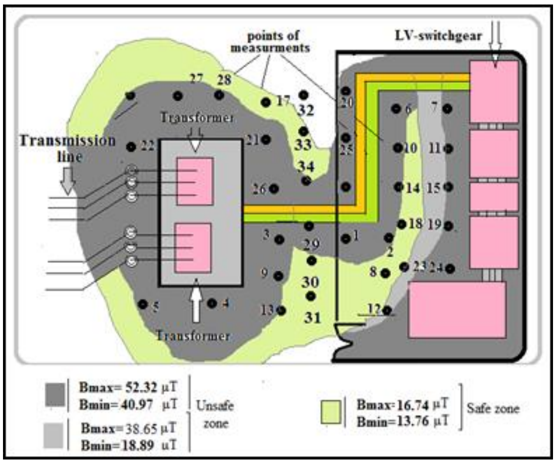

Fig. 5: The safe and unsafe zones of the electric and magnetic fields that emitted from the circuit breaker inside the substation.

5. RECOMMENDATIONS

The following recommendations may be listed in order to direction the risks:

1. To avoid overexposing to the magnetic fields, the worker must be at a safe distance from the magnetic fields sources, i.e., out of the unsafe zones.
2. Worker must avoid sitting or sleeping for long Perion near the electrical equipment, especially those with motors.
3. EMF exposures are exist in the workplaces as a result of all types of electrical equipment and building wiring. So it is wise to move away any unnecessary equipment.

4. The workers must avoid unnecessary exposure to a high magnetic fields sources by Reducing the exposure time in the EMF field.
5. The workers must keep away from the equipment when it is running.
6. Ferromagnetic materials shielding creates an alternative path for the magnetic flux. So, it's better to shield the equipment that are considered a source of high magnetic field in order to reduce the risk.
7. During the measurements of the electromagnetic field of a high level and intensity, it is advisable to consider the following precautionary measures:
   a- Measurement should be located in the expected peak field places where.
   b- Measurements are recommended to be conducted over the period.

6. CONCLUSIONS

From this work, the following conclusions may be deduced:

Measurement of the electromagnetic field levels in the exposure workplaces becomes very important issue with the rapid and continuous increase of the electricity demand. This research presented a survey of an electromagnetic field measurements for 132/33 kV power substation. The survey was carried out in the power substation under actual loads and conditions. The obtained results have been compared with the international established limitation standards. From the mathematical calculations and the actual measurements, it could be noticed that the results meet the international exposure limits that set by the (ICINRP). Analyzing the obtained results proved that there are no health risks due to the work in the equipment in zone the substation provided that, the work should be achieved within a short period.

The obtained results could be used as a useful data base for analyzing and estimating the possible occupational exposure levels that encountered by the workers in many zones in the substation area. It is also useful determine the safe and unsafe zones around the electrical equipment inside the substation to in order avoidts.

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