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Investigate and Analyze the Electromagnetic Field Levels Inside Electric Power Substation

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Abstract

Electric power transformers are a very important part of modern electric power and transmission line network systems and they consider as a high level source of electromagnetic fields which can affect the health of workers in station. In this research, electric and magnetic fields caused due to the operation of power distribution substation of 132/33 kV are investigated in order to avoid the overexposure of these fields to workers. Research has been conducted on both the mathematical calculations and practical measurements. The intensities of electric and magnetic fields have been measured at substation by EMF tester device. Safe zones from some equipment have been determined. Comparison the obtained results with the standard safety guideline limits shows that they are within the acceptable limits.

Keywords: Electric power distribution substation, electromagnetic field, health effect.

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.

***الكلمات الدالة*: محطة توزيع فرعية، المجالات الكهرومغناطيسية، التأثير على الصحة.**

Introduction

Every day, we expose to electromagnetic fields from different sources of electric and magnetic fields (EMF) 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

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compensation and power cables [2]. Some researchers have embraced the effects of EMF on human health due to the association of electromagnetic fields with increasing of behavioral changes and health problems such as epilepsy, cancer, brain tumors. Disorders [3].

EMFs are lines of force surround electrical wires or devices. These fields consider as time-varying quantities characterized by some parameters, such as frequency, phase and magnitude. Electric and magnetic fields both are weaken with increasing distance from the its source. Electric fields can be easily weakened by objects such as buildings, trees or human skin but magnetic fields cannot because they able to pass through anything which doesn't contain a high concentrations of iron [4].

Some organizations have been established and set some guidelines limits for limiting the EMF exposure to avoid adverse health effect. The (ICNIR) which established in 1998 and issued its guidelines exposure limits. Table (1) illustrates the limit levels of 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 electromagnetic fields.

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

Literature Review

For estimating the intensity of electromagnetic fields, the following paragraph give a briefing of some studies about the biological effects of electric and magnetic fields.

1- Feychting, Verkasallo et al in 1993, Tynes in 1997 conduct some calculations based methods. As early findings which indicated an increased danger of childhood diseases of children living in industrial cities directly exposed to high voltage power lines due to bad conditions in housing safety is very dangerous to their health [6].

2- Reilly conduct a study in 1978 by standing 122 men directly near overhead transmission lines in various conditions; 90% of them could perceive a 20 kV/m 60 Hz electric field, and perception reached a self-reported 'annoyance' threshold for 10%. A small percentage reported perception at field strengths below 5 kV/m [7].

3- Graham in in his study of electric fields (0–15kV/m) and magnetic fields (0–40mT) on 10 men and 10 women aged (21–35). The threshold of 90% of the group was 39 kV/m. Perception improved when the field onset was abrupt and when the volunteer changed his position under the effect of field. Perception of field onset ceased after about 20min of exposure but was immediately reestablished by human movements within the field [8].

Methodology

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

1- Mathematical calculations.

2- Practical measurement.

3- Determining the safe and unsafe ranges from some power equipment that are in attach with the workers due to performing their daily works in power substation. Investigation of electric and magnetic fields in the substation has been performed in two steps:

Mathematical calculations.
Practical measurements.

Mathematical Calculations

To calculate the magnetic field of the straight wires by using the Biot-Savart law [9]. If an infinite straight conductor, directed along with the z-axis carrying a current ***I*** as shown in Figure (1).

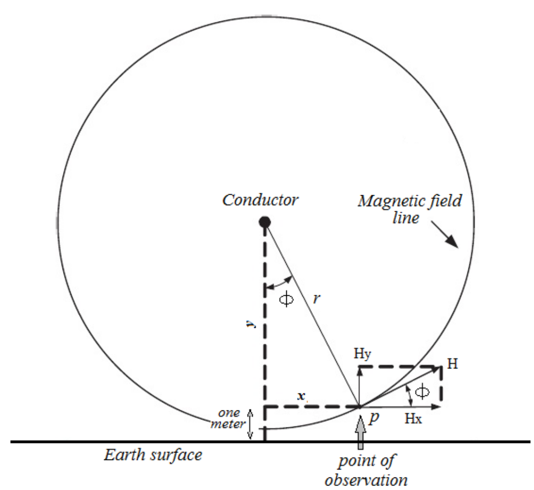

Fig. 1. Geometry to calculate the magnetic field at the point p (*x* , *y*) due to the phase conductor.

The distance between the small segment ***dl*** and the point is ***r***, then the magnetic field contribution by the individual segment ***dl*** at point ***P*** will give as follows:

$$\begin{aligned} B_\theta &= \frac{\mu_0}{4\pi}\int_{-\pi/2}^{\pi/2}\frac{I\,\rho}{\rho^3\,(\cos\phi)^{-3}}\frac{\rho}{\cos^2\phi}\,d\phi \\ &= \frac{\mu_0\,I}{4\pi\,\rho}\int_{-\pi/2}^{\pi/2}\cos\phi\,d\phi = \frac{\mu_0\,I}{4\pi\,\rho}\left[\sin\phi\right]_{-\pi/2}^{\pi/2}, \end{aligned} \quad (1)$$

$$\mathbf{I}\times(\mathbf{r}-\mathbf{r}') = I\rho\,\hat{\boldsymbol{\theta}},$$

$$dl = \frac{\rho}{\cos^2\phi}\,d\phi, \quad (2)$$

$$|\mathbf{r}-\mathbf{r}'| = \frac{\rho}{\cos\phi}.$$

$$\mathbf{B}(\mathbf{r}) = \frac{\mu_0}{4\pi}\int\frac{\mathbf{j}(\mathbf{r}')\times(\mathbf{r}-\mathbf{r}')}{|\mathbf{r}-\mathbf{r}'|^3}\,d^3\mathbf{r}', \quad (3)$$

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

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

Table 2: currents values.

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

Practical Measurement

These measurements were performed on a 2m×2m grid at a height of one meter above the ground in the substation as illustrated in Fig. (2).

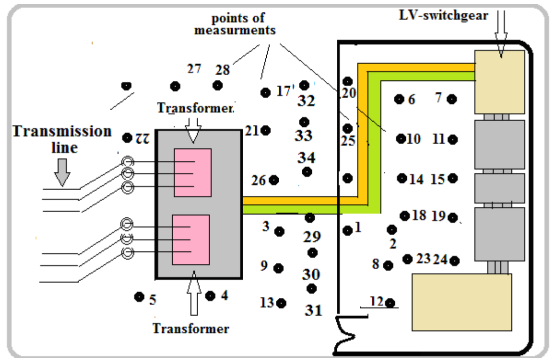

Fig. 2. Measurement points in the substation

Measurements of electric and magnetic fields are conducted by using EMF tester (PMM 8053).

Results and Discussion

By applying equations above, the mathematical results will be shown 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 measuring results of electric and magnetic flux are given in Tables (4) and (5). Average values of calculated and measured values are shown in Table (6).

Table 4: Measuring results of electric and magnetic fields near the transformers.

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

Table 5: Measuring results of electric and magnetic fields near 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 calculated and measured values.

Area	Point No.	B(μT)	E (V/m)
Near the LV Switchgear	23	36.40	1490
	14	31.64	139
	15	14.72	8
	16	32.87	796
	17	38.65	1292
	18	31.73	1843
	19	18.89	113
	20	35.54	2
			987
			1651
Average		24.62	1325

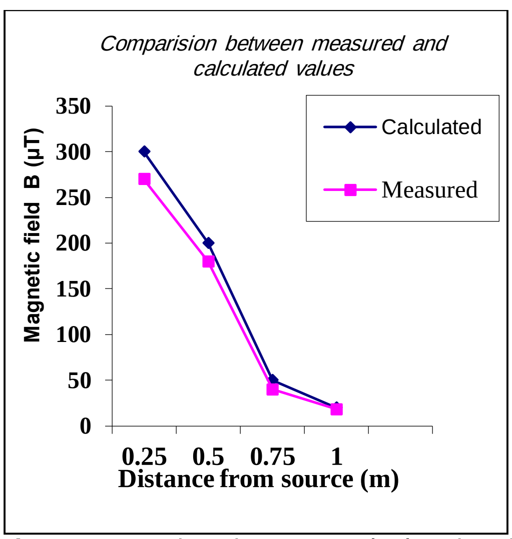

Fig. 3. Comparison between calculated and measured values of magnetic flux density

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

Measured results of (E) and (B) at three ranges from sources are shown in Tables (7) and (8) while the graphic representation of results are illustrated in Figs. (3) and (4).

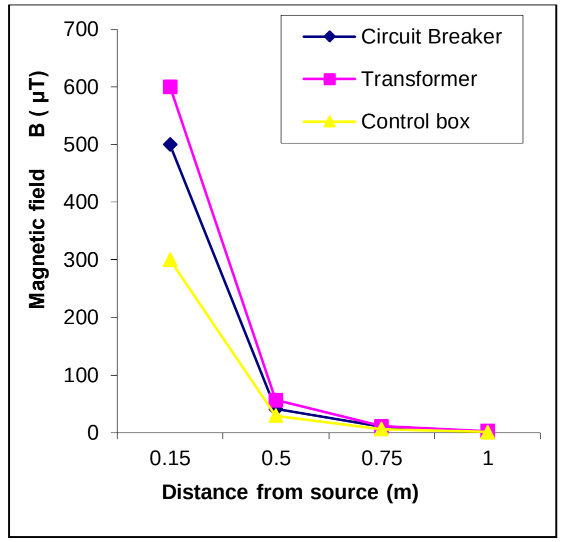

Fig. 4. Graphical representation of measured results of magnetic field density (B) for three ranges from the sources

Table 7: Measured results of (E) at three ranges from some sources.

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 three ranges from some sources.

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

Based on the obtained results, it can be conclude the following:

- From Table (6) we can see that there is a deviation between the calculated and measured values in the range of approximately 9 % to 12% in the switchyard and near the transformers. The reason may be because the model does not consider the actual operating data of the plant or not sufficiently detailed.
- Measurements fell within the standard limit recommended by the ICNRP;(500µT) and (10kv/m) for occupational exposure as indicate in Table (1).
- From Tables (7) and (8) we can determine the safe zones from source of EMF as follows:

Circuit Breaker

a- For a range of 0.15m from the (Circuit Breaker), (B=542µT>500µT) and (E=11315 V/m > 10KV/m), so it is unsafe range (zone) according to the international exposure limits set by the ICNRP for occupational exposure limits level (B = 500 µT and E= 10KV/m).

b- For a range of 0.3m from the (Circuit Breaker) emits (41.21µT<500µT) and (E=4315 V/m <10KV/m), so it is a safe zone.

c- For a range of 0.75m from the (Circuit Breaker) emits (11.41µT<500µT) and (E=1420 V/m < 10KV/m), so it is a safe zone.

Transformer

a- For a range of 0.15m from the Transformer, (B=669.6µT>500µT) and (E=12978V/m>10KV/m), so it is not a safe range (zone).

b- For a range of 0.3m from the Transformer, (B=56.6µT<500µT) and (E=5278V/m<10KV/m), so it is a safe zone.

c- For a range of 0.75m from the Transformer, (B=11.41µT<500µT) and (E=1583V/m<10KV/m), so it is a safe zone.

Control box

a- For a range of 0.15m from the Control box, (B=312.62µT<500µT) and (E=8575V/m<10KV/m), so it is a safe range (zone).

b- For a range of 0.3m from the Control box, (B=29.62µT<500µT) and (E=29.62V/m<10KV/m), so it is a safe zone.

c- For a range of 0.75m from the Control box, (*B*=6.36µT<500µT) and (*E*=1127V/m>10KV/m), so it is a safe zone as illustrated in Fig. (5).

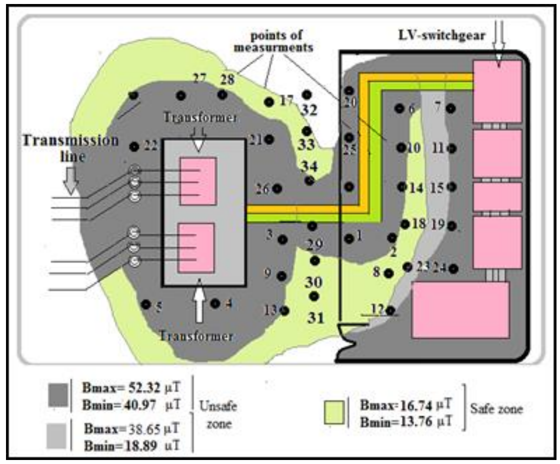

Fig. 5: The safe and unsafe ranges of the electric and magnetic fields emitted from the circuit breaker inside the substation.

Recommendations

1. To avoid the overexposure to magnetic fields, the worker must keep away as possible from the magnetic fields sources taking into account the save and unsafe zones.
2. The worker must not sleep or sit for a long periods of time near 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 better to move any unnecessary equipment.
4. The workers must avoid unnecessary exposure to high magnetic fields sources by Reducing spent time in the field.
5. The workers must be stay back from equipment when it running.
6. Ferromagnetic material shielding creates an alternative path for the magnetic flux. So, it's better to shield the equipment that represents a source of high magnetic field to reduce the negative effects on workers' health.
7. During the practical measurements of electromagnetic field level advisable to consider the following:
8. Measuring points should be located in places where expected peak field.
9. Measurement is recommended to be conduct throughout work conditions.

Conclusions

Measurement of electromagnetic field exposure levels in workplaces become very important issue with the increasing of electricity demand. This research presents a survey of electromagnetic field measurement in the 132/33 kV power substation. The survey was carried out in the power substation under actual loads. The obtained results have been compared with the international established limitation standards. From the mathematical calculations and the practical measurements, we can notice that both measuring results of determining the electric and magnetic levels are seeming to be much lower than the international exposure limits set by the (ICINRP). Analyze the obtained results indicate that there are no health risks from working with this equipment in substation if working time is for a short and not continues periods.

The results obtained can be used as a useful data for analyzing and estimating possible occupational exposure levels encountered in various points in the substation and determining the safe and unsafe ranges from electrical equipment in this substation to avoid its negative health effects.

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