USING NEW TECHNOLOGICAL METHODS IN DEFINING SAFE RANGES FOR ELECTROMAGNETIC RADIATIONS IN BUILT ENVIRONMENT

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ABSTRACT

The dangers of electromagnetic radiation occur when humans works in the operation, following and maintenance of the transforms which causes their exposure to the electromagnetic field for long periods of time, and also when transformers are placed in the residential buildings its fields affects the health of all those living in this building. This paper aims to study the environmental and health dangers caused by the electromagnetic fields produced by the medium voltage transformers found in or near the residential and services buildings.

Because of all the fears from the electromagnetic fields many researches and studies were performed, the world health organization started an international project to evaluate the environmental and health effects caused by the electromagnetic field with its different frequencies, many authorities and organizations supported this project, The international Commission on Occupation Health (ICOH), The World Federation for Ultrasound in Medicine and Biology (WFUMB), The International Organization for Medical Physics (IMOP) The International Radiation Protection Association (IRPA), The International Committee on Electromagnetic Safety (ICES), and this project is referred to as the International Electromagnetic fields Project (International EMF Project)

Despite all environmental and health dangers, and in spite of all the fears from these dangers, the Egyptian law of electricity no. issued on 2015 did not define any safe limits for the medium voltage transformers but only defined in statement 55 the safe limits for all types of cable lines, also almost all the electromagnetic fields studies concentrated on the study of effects of high voltage power lines and the mobile phone networks, but studies of the environmental and health dangers of the electromagnetic fields produced by medium voltage transformers are very rare.
Keywords: EMF, Electromagnetic field, Medium Voltage Transformers, Land-use.

INTRODUCTION

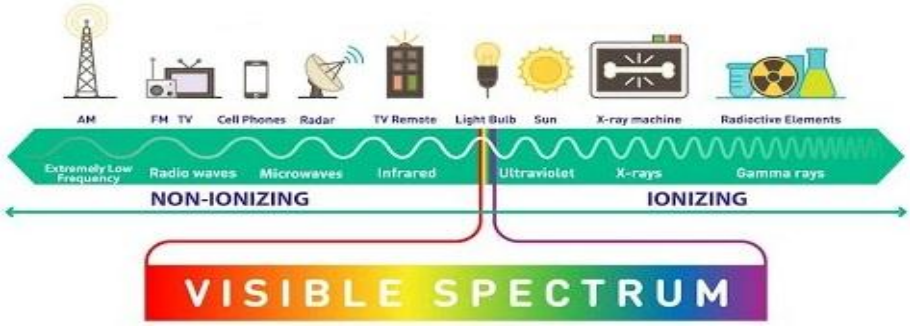
Electromagnetic waves are produced by the motion of electrically charged particles. These waves are also called electromagnetic radiation because they radiate from the electrically charged particles. They travel through empty space as well as through air and other substances. Electromagnetic waves at low frequencies are referred to as electromagnetic fields and those at very high frequencies are called electromagnetic radiations (Stephen McKnight and Christos Zahopoulos, 2015).

1) **Classification of electromagnetic waves:** According to their frequency and energy, electromagnetic waves can be classified as either ionizing radiations or non-ionizing radiations (NIR).

Ionizing radiations are extremely high frequency electromagnetic waves (X-rays and gamma rays), which have enough photon energy to produce ionization by breaking the atomic bonds that hold molecules in cells together.

Non-ionizing (NIR) is a term for that part of the electromagnetic spectrum which has photon energies too weak to break atomic bonds. They include ultraviolet radiation, infrared radiation, radiofrequency and microwave fields (Semak, . Shneider - 2015).

NIR can't cause ionization however have been shown to produce other biological effects, for instance heating, altering chemical reactions or inducing electrical currents in tissues and cells.



Fig(1): Electromagnetic Spectrum

There are four subgroups of electromagnetic radiation fields with frequency and intensity. This electromagnetic spectrum begins at a frequency of one Hertz (Hz), which is one wave per second.

A) Static electric: Stationary electric charge that is built up on the surfaces and materials. Electric fields are associated with the presence of electric charge, magnetic fields result from the physical movement of electric charge. Human body can not feel less than 2000 volts of static discharge. Magnetic fields can exert physical forces on electric charges when charges are in motion. The magnetic flux density measured in teslas (T), is

accepted as the most relevant quantity for relating to magnetic field effects.

B) Low Frequency (ELF): Extremely low frequency is a term used to describe radiation frequencies below 300 Hertz (Hz). ELF fields are oscillating fields and very important for public health because of the widespread use of electrical power at 50-60 Hz in most countries.

C) Intermediate Frequency (IF): Intermediate Frequency is a term to describe radiation frequency between 300 Hz and 100 kHz. There are experimental and epidemiological data from the IF range. Therefore, assessment of acute health risks in the IF range is currently based on known hazards at lower frequencies and higher frequencies. Proper evaluation and assessment of possible health effects from long term exposure to IF fields are important because human exposure to such fields is increasing due to new and emerging technologies.

D) Radio Frequency (RF): RF is includes the frequencies between 100 kHz and 300 GHz of the electromagnetic spectrum. RF sources are widespread used in whole world. Majority examples are mobile phones, broadcasting, medical and industrial applications. The RF sources are used in different frequency bands.

Table(1): Classification and sources of electromagnetic radiation fields (Reitz. *et.al*. 2008)

Type	Frequency range	Source
Static	0 Hz	Natural Video MRI Industrial electrolysis
Extremely low frequency (ELF)	(0< f ≤300 Hz),	Power lines Domestic distribution Electric engines in cars, train and tramway
Intermediate frequency (IF)	100 Hz < f ≤ 300 kHz	Monitors, Anti-theft devices in shops, Hands free access control systems, Card readers Metal detectors
Radio frequency (RF)	100 kHz< f≤ 300 GHz	Broadcasting and TV; Mobile telephony Microwave oven Radar Portable and stationary radio transceivers, Personal mobile radio

The electromagnetic properties of any material can be determined by the following constitutive relations (Tipler and Mosca 2008).

$$\vec{D} = \varepsilon \vec{E}$$

$$\vec{B} = \mu \vec{H}$$

$$\vec{J} = \sigma \vec{E}$$

where the permittivity ε is measured in units of farads/m (= coulombs/volt m), describes the effect of dielectric material on the external $\vec{D}$ field the yields the $\vec{E}$ field inside the material; the permeability μ is measures in units of Henries/m (= kg m/coulombs^2) describes the effect of a

magnetic material on the external $\vec{H}$ field that yields the $\vec{B}$ field inside the material; and the conductivity σ in Siemens/m (= 1/ohm m) which describes the charge current density $\vec{J}$ that is caused by a given electric field $\vec{E}$ in a conducting material. In free space (vacuum) $\epsilon = \varepsilon_o = 8.8543 * 10^{-12}$ F/m, $\mu = \mu_o = 4\pi * 10^{-7}$ H/m, and $\sigma = 0$, since there are no charges in complete vacuum.

The last major equation of electromagnetics describes the forces that the electromagnetic fields exert on the objects. The electromagnetic force on an object with charge q moving with velocity $\vec{v}$ is described by the Lorentz force.

$$\vec{F} = q\vec{E} + q\vec{v} \times \vec{B}$$

The Lorentz force is a combination of the Coulomb's Law force between two charges, the opposite charges attract and like charges repel (first term) and the magnetic force on a moving charge is perpendicular to the particle's velocity and to the magnetic flux density (second term). Lorentz force equation is the source of all electromagnetic forces.

To the first approximation, macroscopic objects are commonly electrically neutral while electromagnetic force on large objects typically arises because:

1. The electric field causes charge separation and creates a net electrostatic attraction or repulsion, or
2. Only the negative electrons in a bulk metal or metal wire – is moving, while the positive ion cores are immobile.

In this second case, the force on the object can be expressed in terms of the current carried by the mobile carriers.

2) **The effects of electromagnetic fields on human health:** Since the beginning of the 20th century, we are overwhelmed by the increasing sources of the Electromagnetic Field (EMF) that is coming from telecommunication, electricity, appliances, medical equipment and many other apparatus that are used in daily life. Although these new technologies became inevitable and indispensable, the EMF they produce may cause health risks and hazards to human (Poljak and Cvetkovi´c, 2019).

Some studies show a link between exposure to EMF and increased rate of Leukemia, cancer, brain tumors and other health problems. Also, there is some uncertainty remains as to the actual mechanisms responsible for these biological hazards and which type of fields magnetic or electric or both are of great concern (Ahmed, 2009).

It is needless to say that no matter the effects of these EMF be trivial or catastrophic, we should take all the necessary precautions to reduce our exposure to EMF as low as reasonably attainable. For this to occur, all those involved or affected by this exposure should follow the RF safety standards and guidelines set forth by the regulatory authorities like the Ieee, Who, Icnirp, and other likewise organizations.

Any failure in taking immediate actions to the above guidelines, the public would be at a high epidemic risk of potentially fatal diseases in the

future.

3) Hazard of Electromagnetic Fields: Hazards from Electromagnetic pollution can be in various forms. It can be electrical hazards, fire hazards, biological hazards and DNA fragmentation (Zamanian and Hardiman, 2005).

A) Electrical Hazards: Strong radiation can induce current capable of delivering an electric shock to persons or animals. It can also overload and destroy electrical equipment. The induction of currents by oscillating magnetic fields is also the way in which solar storms disrupt the operation of electrical and electronic systems, causing damage to and even the explosion of power distribution transformers, blackouts (as in 1989), and interference with electromagnetic signals (e.g. radio, TV, and telephone signals).

B) Fire Hazards: Extremely high power electromagnetic radiation can cause electric currents strong enough to create sparks (electrical arcs) when an induced voltage exceeds the breakdown voltage of the surrounding medium (e.g. air). These sparks can then ignite flammable materials or gases, possibly leading to an explosion. This can be a particular hazard in the vicinity of explosives or pyrotechnics, since an electrical overload might ignite them. This risk is commonly referred to as Hazards of Electromagnetic Radiation to Ordnance (HERO)

C) Biological Hazards: The best understood biological effect of electromagnetic fields is to cause dielectric heating. For example, touching

or standing around an antenna while a high-power transmitter is in operation can cause severe burns. These are exactly the kind of burns that would be caused inside a microwave oven. This heating effect varies with the power and the frequency of the electromagnetic energy. A measure of the heating effect is the specific absorption rate or SAR, which has units of watts per kilogram (W/kg). The Institute of Electrical and Electronics Engineers (IEEE) and many national governments have established safety limits for exposure to various frequencies of electromagnetic energy based on Specific Absorption Rate (SAR), mainly based on International Commission on Non-Ionizing Radiation Protection (ICNIRP) Guidelines, which guard against thermal damage (National Research council (2003) : Possible health effects of exposure to residential electric and magnetic fields, National Academy Press, Washington DC).

Many studies around different universities around the world were carried out and it was found that intermittent (but not continuous) exposure of human cells to a 50 Hz electromagnetic field at a flux density of 1mT induced a slight but significant increase of DNA fragmentation in the Comet assay. However that level of exposure is already above current established safety exposure limits.

Table (2): Standards Safe limits of exposure to electromagnetic fields

SCIENTIFIC BODY	Proposed safety limit (flux density) in mG (milli Gauss)
WHO = World Health Organization = World Health Organization (International Agency for Research on Cancer)	3-4
NCRP = National Council Of Radiation Protection and Measurement = National Council on Radiation Protection	2
TCO = Ecological Model for electronic devices (distance 30 cm)	2
argeTQ = green Austrian residential certificate	2
ÖKOPASS = residential certification, Austrian Institute of Biology Building (IBO)	1
Austrian Medical Association	1
German Building Biology Institue IBN (Institut für Baubiologie + Ökologie Neubeuern - Recommendations for the bedrooms)	1
BioInitiative Working Group (international team of scientists that reviews data from over 2000 studies on the effects of electromagnetic fields)	1
Levels in nature	<0,000002

World Health Organization (WHO) Model legislation for electromagnetic fields protection. Geneva, Switzerland: 2006)

4) Objectives: This Research aims to study the electromagnetic fields around the medium voltage transformers located in residential, services and commercial areas and propose methods of protection from these fields.

MATERIALS

The study analyzes the measurements of the electromagnetic field performed by author in a medium voltage transformer located in a service plant within a residential area and proposes a protection method that can be applied without causing any economical or application stress over the economic studies of any new medium voltage transformer plant to be established ever after .

EMF Magnetometer

1. To measure the Electromagnetic Flux around the medium voltage transformers.
2. To perform the measurements again with the proposed methods of protection

Fig.(2) : EMF Magnetometer

- Medium voltage transformers with different loading percentages.
- Standard safety limits defined by international health agencies to ensure its application with our proposed protection methods.

- Studies, references and internet sites that discuss our research target and any problems that were previously discovered.

METHODS

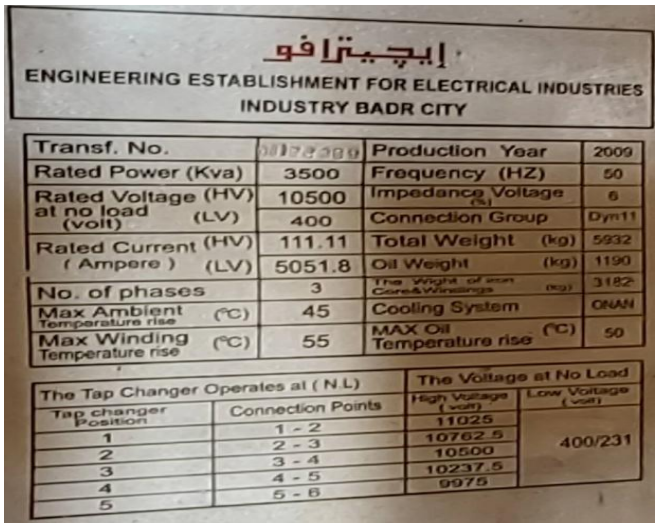
Using the Magnetometer device to measure the electromagnetic flux around the medium voltage transformer located in "Extension of Tokh water supply station" constructed by Societe Egyptienne D'Entreprises – Moukhtar Ibrahim.

Fig(3): Banner shows the name and location of the chosen measurement point

The following are photos of the transformer room located on the site, this transformer is loaded by the operation loads of the original water supply station other than the extension works that did not start operation yet.

Fig(4):

Fig(5):



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Transf. No.	[illegible]	Production Year	2009
Rated Power (Kva)	3500	Frequency (HZ)	50
Rated Voltage (HV) at no load (volt)	10500	Impedance Voltage (%)	6
(LV)	400	Connection Group	Dyn11
Rated Current (HV)	111.11	Total Weight (kg)	5932
(Ampere) (LV)	5051.8	Oil Weight (kg)	1190
No. of phases	3	The Wight of iron Core&Windings (kg)	3182
Max Ambient Temperature rise (°C)	45	Cooling System	ONAN
Max Winding Temperature rise (°C)	55	MAX Oil Temperature rise (°C)	50

The Tap Changer Operates at (N.L)		The Voltage at No Load	
Tap changer Position	Connection Points	High Voltage (volt)	Low Voltage (volt)
1	1 - 2	11025	400/231
2	2 - 3	10762.5	
3	3 - 4	10500	
4	4 - 5	10237.5	
5	5 - 6	9975	

Fig(6):

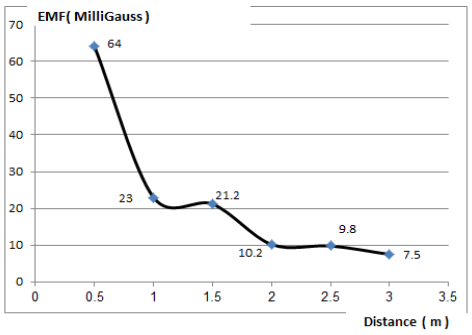
(Fig. 4, 5, 6 & Table 3) : The transformers room and specifications

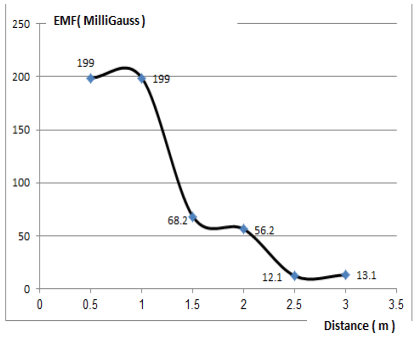
Prodution Company	Egytravo
Primary Voltage (input)	10500 Volt
Secondary Voltage (output)	400 Volt
Power	3500 KVA
Frequency	50Hz
Room Area	70 m2 (7m x 10m)

The measurements of the electromagnetic flux came out with the following values:

Table (4): Measurements of the electromagnetic flux

Distance (m)	0.5	1	1.5	2	2.5	3
High Voltage Side						
EM Flux (Melligauss)	64	23	21.2	10.2	9.8	7.5
Low Voltage Side						
EM Flux (Melligauss)	199	199	68.2	56.2	12.1	13.1





Fig(7): Measurements at the high voltage side	**Fig(8):** Measurements at the low voltage side

Knowing that the safe range of exposure to the electromagnetic flux must not exceed the range of 5 milligauss, the measurements values shows that as long as the workers are within the 3 meters boundary around the transformers they are

exposed to a very strong and harmful range of electromagnetic flux that is very dangerous to their human health as well as to the environment.

These measured values led the author to propose a method of protection from the exposure to such dangerous fields, the most economic and applicable method was the lining of the walls of the room of the transformer with a substance that can absorb this electromagnetic flux and provide the in-room workers with a safe environment to work in, this proposed substance was tin, the author used a tin sheet (2m x 2m) that is placed a distances of 2m and the measurements and the author obtained was the following :

Measurements at High Voltage Side :

Table (5): Measurements of the electromagnetic flux at 2m distance at high voltage side

At 2 m. at high voltage side			
	Right	Middle	Left
Without Tin Sheet			
Electromagnetic Flux (Melligauss)	11.8	10.2	9.2
With Tin Sheet			
Electromagnetic Flux (Melligauss)	1.6	4.8	5.6

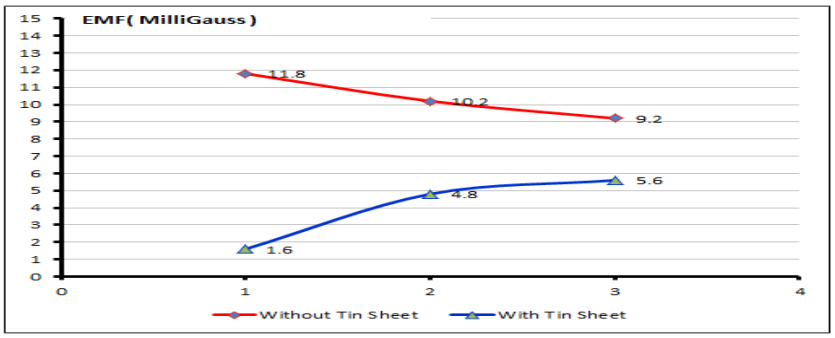


Fig (9): Measurements of the electromagnetic flux at 2m distance at high voltage side

Measurements at Low Voltage Side :

Table (6): Measurements of the electromagnetic flux at 2m distance at low voltage side

At 2 m. at Low Voltage side			
	Right	Middle	Left
Without Tin Sheet			
Electromagnetic Flux (Melligauss)	56.2	26	16.5
With Tin Sheet			
Electromagnetic Flux (Melligauss)	10.8	9.2	9.4

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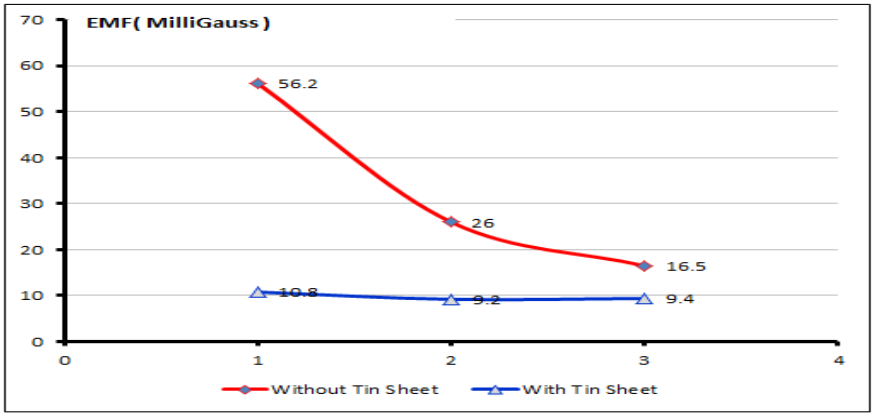

Fig (10): Measurements of the electromagnetic flux at 2m distance at low voltage side

RESULTS AND DISCUSSION

After performing the required measurements that lead to the discovery of the very high electromagnetic field to which all the labor are exposed to, it was of great importance to propose a solution that can provide the labors with a safe environment to work in.

The recommendation by the author was the lining of the medium voltage transformers room walls with galvanized tin sheets, this solution was chosen when the author noticed during performing the measurements at different locations that some of the rooms that have galvanized tin doors, the author got the least measurements beside these doors, so on applying this proposed solution and performing the measurements once again a great difference is achieved.

CONCLUSION

Having the medium voltage transformers rooms within our residential areas is a great disaster that causes the exposure of all the people around these rooms to the produced electromagnetic field densities that affects their health as well as the surrounding environment around them.

In the past, the medium voltage transformers were placed in separate rooms located between the residential buildings and that was dangerous, but nowadays, these transformers are placed inside the residential buildings and that increased the severity of the effects of the electromagnetic field on both, the human health and the surrounding environment.

Fig (11): transformers placed inside residential buildings

RECOMMENDATIONS

- For the medium voltage transformers rooms located inside the residential areas all the walls must be covered with galvanized tin.
- On planning and construction of new communities the medium voltage transformers room must be away from the residential buildings and the safe region around these rooms must be defined.
- Health and environment impact assessment must be applied before locating the medium voltage transformers room before being built.
- The government must have an effective role in monitoring the health effects on those who works around these medium voltage transformers.

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Journal of Environmental Sciences (JES)
Institute of Environmental Studies and Research, Ain Shams University

استخدام التقنيات الحديثة فى تحديد النطاق الآمن لمصادر الأشعة الكهرومغناطيسية فى البيئة المشيدة

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المستخلص

فى غضون المائة عام الماضية عمل الإنسان فى مختلف المجالات الحياتية بشكل كبير ومكثف، تلك الأنشطة قد غيرت من التوزيع الطبيعى للكهرومغناطيسية ، ولسنوات عديدة أبدى العلماء إهتمامهم بشأن الآثار الصحية المحتملة من التعرض للأشعة الكهرومغناطيسية .

إن الإستخدام المفرط للأجهزة الكهربائية أثار سؤالاً هاماً حول التأثيرات الجانبية والسلبية لها على صحة الإنسان، كما كثر الحديث والشكوى من تأثيرات المصادر المختلفة للأشعة الكهرومغناطيسية على صحة الإنسان .

إن العديد من الدراسات والأبحاث التى نشرت على مستوى العالم ناقشت الجوانب السلبية للأشعة الكهرومغناطيسية الناجمة عن كابلات الضغط العالى وإستخدامات الهواتف المحمولة ، لكن هناك العديد من المصادر الأخرى للمجال الكهرومغناطيسى ومنها محور هذا البحث وهو محولات الجهد المتوسط والموجودة بكثرة داخل المناطق السكنية وأصبحت حالياً موجودة بداخل المبانى السكنية.

بدأ البحث بإجراء العديد من القياسات بداخل غرف محولات الجهد المتوسط الموجودة داخل المحيطات السكنية ومحطات الخدمات (مياه شرب او صرف صحي) وبدراسة نتائج القياسات وجد انها تتعدى الحدود الآمنة المسموح بها وان كل العاملين داخل هذه الغرف معرضون للعديد من المشكلات الصحية التى تنتج عن هذا التعرض ولذلك كان من المهم إيجاد حلول لهذه الكميات من المجال الكهرومغناطيسى.

أثناء إجراء القياسات فى العديد من الغرف تنبه الباحث الى انه كان لبعض الغرف ابواباً من الصاج المجلفن فكانت القياسات تسجل أدنى قراءات بالقرب من هذه الأبواب ، لذلك بدأت الباحثة فى إجراء القياسات مرة أخرى باستخدام الواح من الصاج المجلفن وكانت القياسات مختلفة تماماً حيث قامت الألواح من امتصاص المجال الكهرومغناطيسى والوصول به الى القيم المقاربة للحدود الآمنة للتعرض ولذا كانت توصيات البحث بأن يتم تبطين الغرف التى يتواجد داخلها محولات الجهد المتوسط بالواح الصاج المجلفن وإعتماد هذا الإقتراح فى الكود المستخدم فى المبانى.