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ASSESSMENT OF SAFETY DISTANCE FROM TRANSMISSION LINES RADIATION: A CASE STUDY OF POWER LINES IN OYO STATE NIGERIA

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Abstract - The International Commission for Non-Ionizing Radiation Protection (ICNIRP) approved magnetic limits for transmission lines. The "safe distance" from an EMF source is simply the measured distance needed to reduce human exposure to some desired safety levels in most cases. The International Radiation Protection Association (IRPA) recommends measuring the strength of the electrical and magnetic fields for evaluation of the safety distance from transmission lines. Therefore, this research focused and experimentally examined the level of magnetic and electric field radiation from 330Kv, 32Kv, and 33KV lines in Ibadan, Oyo State, Nigeria. The assessment is based on the safety limits recommended by (ICNIRP 1998). In the measurement, the Holaday HI-3604 ELF survey was used to measure the fields in the vicinity of the lines at horizontal distances (0-100m) and vertical distances of 1.5m. The theoretical assessment was used, and the Biot-Savart law was used to estimate the occupational and general public exposure limits based on the comparison of measured power flux density, magnetic fields were estimated. The highest magnetic and electric fields measured from the base of the transmission lines were recorded to be 7.17µT and 6.0V/m, respectively. Thus, at 25m (RoW for 330Kv), the magnetic field is 4.10µT which is about 0.82% for the general public and 0.41% for occupational base on ICNIRP data recommended value. Thus, at 25m (RoW for 330Kv), the electric field is 2.91V/m, which is about 0.58% general public and 0.3% occupational based on ICNIRP data recommended value.

Keywords - Power Flux Density, Safety Distance, Magnetic Field, and Electric Field

I. INTRODUCTION

For several decades, high voltage power lines, once suspected of being a cause of childhood leukemia and other illnesses, have driven down property values and scared homeowners into fearing for their health (EPA, 1990). Subsequent research has shown the link between power lines and physical ailments, and those who live near these lines are exposed to the effects. However, the quality and essentiality of life of an inhabitant are determined by health and comfort, which depend on the surrounding environment, either indoors or outdoors (Bluyssen 2010). Decisions are made during a building's early design stages to determine its energy consumption and environmental impact (Basbagill et al. 2013; Kohler and Moffatt 2003; Schlueter and Thesseling 2009; Scheuer et al. 2003). In addition, the impact of urban geometry on outdoor thermal comfort and air quality has been considered.(Krüger et al. 2011). However, the impact of environmental pollution from high-tension transmission lines on the outdoor environment in the proximity of new development was almost overlooked. The extremely low frequency in the magnetic field environment is usually characterized by its flux density, which is measured in units of Tesla (T) or microTesla (µT). The generality of the populace is becoming increasingly uncomfortable and is daily expressing their fears about the possible ugly consequences of the exposure to radiation from these lines. This issue is important to prevent the problems associated with the interaction between buildings, dwellers, and their environment (Lord and Wilson 1980) by evaluating actual EMF conditions (Richman et al. 2014). High-tension power lines are considered the major sources of electric and magnetic fields, or ELF. Studies have shown that people living close to high voltage power lines have a higher likelihood of exposurere to ELF radiation, and this could consequently cause symptoms like nausea, fatigue, headache, and sleeplessness [1,2]. The rapid increase of electric energy demand and increase in the use of electricity have resulted in a dense transmission line network that has been oriented within urban areas, exposing the general public to associated EMF. The exposure levels for the general population are typically 0.01 to 0.2 µT (0.1 to 2 mG) for magnetic fields (ICNIRP 1998).

1.1 Interaction of the Human Body with the Magnetic Field of a Power Line.

Exposure to power lines results in internal body currents and energy absorption in tissues as a result of thermo-molecular agitation thatdepends on the coupling mechanisms, the frequency(f), and the electrical conductivity of the medium (σ). In magnetic media, permeability (µ)relates magnetic field intensity (H) to magnetic flux density (B) by

$$B=\mu_0 H \qquad (1)$$

From Ohm's Law, the current density (J) depends upon the magnetic flux density (B), field frequency (f) derived from Faraday's law of induction, and radius of the induction loop (R) (Stuchly and Xi, 1994, Ibrahim, M. 2011) and it can be expressed mathematically as

$$J = \pi RfB \text{ ……………………………….(2)}$$

The magnetically-induced electric currents are greatest at the periphery of the body. The maximum ground-level magnetic field strengths associated with overhead transmission lines are of the order of 0.01 - 0.05 mT (it is either on the centreline or under the outer conductors) and are also related to line-height. The magnetic flux density decreases in an approximately linear fashion with distance from the conductor.(Zaffanella and Deno, 1978). Thus, a magnetic field induces a subtle electric current within the body. There are two types of electric current caused by magnetic field induction (Zaffanella and Deno, 1978): circulating current inside the object (eddy current) and current entering/leaving the object. These currents could affect biological processes in the body. The eddy current induced in the body is not conducted to ground and it causes voltage difference within the body which may be as high as 1 mV if the magnetic flux density reaches approximately 0.028 mT (Hauf, 1982, Ibrahim, M. 2011).A study of the effect of electric field exposure on human beings was presented in [5]. They observed that at a certain distance, humans are most likely to experience these health threats: the ground (0 m), exposure of the heart (1.5m), and brain exposure (1.8m).

II. DETAILS EXPERIMENTAL

2.1. Materials and Procedures

This research entails determining the safe distance from transmission lines in a specified city in South Nigeria on a site-specific basis. The present survey was conducted by measuring EMFs at different areas in Ibadan, Oyo State, Nigeria.Ibadan (south west, Nigeria) is the largest metropolis in West Africa; and operates on these three transmissions and substation lines that run through the city for industrial and commercial purposes. This study analyzed the high voltage power lines that run through some commercial areas in Ibadan due to the presence of various factories and parastatals. These include the Hamzee clothes and fabric industry. Nigeria Army Barrack Ojoo , Egbeda local government Secretariat, Nigeria Breweries, the popular Gbagi market, Ibadan Nigerian Institute of Science Laboratory Technology, and the Catholic Major Seminary School of Saints Peter and Paul, to name a few. The following materials were utilized in this project: Measuring Tape, Table, Transmission Lines, The Holaday HI-3604 ELF survey meter was placed 1m away from the foot of the transmission tower throughout the measurement to determine the magnetic fields at that distance (D). The measuring tape was used to determine the needed distance between the table's foot and the power line tower.The power flux density was measured at various distances at the base of transmission lines (0-100m) the electricand magnetic fields observed were evaluated.

Figure 1:Holaday HI 3604 survey meter for ELF.

Holaday HI-3604 ELF survey meter has a magnetic field probe designed to evaluate both electric and magnetic fields associated with 50/60 Hz power lines.

Tables and Graphical Analysis of Measured Data.

Figures 2a-4b represent graphical representation of Electric and magnetic fields as a function of distance from the foot of power transmission lines 330Kv,132Kv and 33Kv,Ayede-Egbeda community, University of Ibadan road, and Shasha Ojo respectively.

Distance (m)	330KV		132KV		33KV	
	E-Field (V/m)	M-field (µT)	E-field (V/m)	M-field (µT)	E-field (V/m)	M-field (µT)
Base 0	6.00	7.17	5.20	5.92	1.20	3.03
10	5.20	6.26	5.05	5.86	1.15	2.89
20	4.68	6.10	4.92	5.54	0.98	2.66
30	4.00	5.01	4.25	5.20	0.83	2.20
40	3.12	3.52	4.00	4.94	0.82	1.89
50	2.55	2.80	3.89	4.78	0.77	1.64
60	1.63	1.86	2.00	4.51	0.70	1.48
70	1.12	1.26	1.84	4.30	0.65	1.20
80	1.06	1.12	1.62	3.83	0.60	0.98
90	0.88	0.90	1.20	2.26	0.57	0.88
100	0.74	0.93	1.00	2.05	0.55	0.74

Table 1.

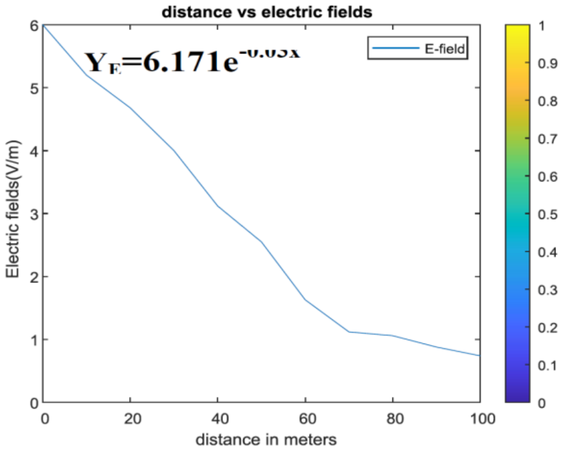


Figure 2a: Graph of the Electric fields from 330Kv power transmission lines at Ayede-Egbeda community as a function of horizontal distance.

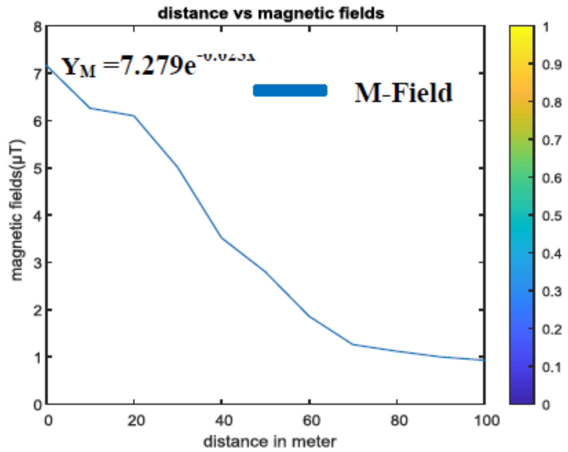


Figure 2b: Graph of the Magnetic fields from 330Kv power transmission lines at Ayede-Egbeda community as a function of horizontal distance.

$Y_E=6.171e^{-0.03X}$ from this function, Y_E is the Electric field and X is the horizontal distance from the foot of the power transmission line. Thus, at 25m (RoW for 330Kv) the electrical field will be 2.91V/m which is about 0.58 % general public exposure limits of the ICNIRP data recommended value.

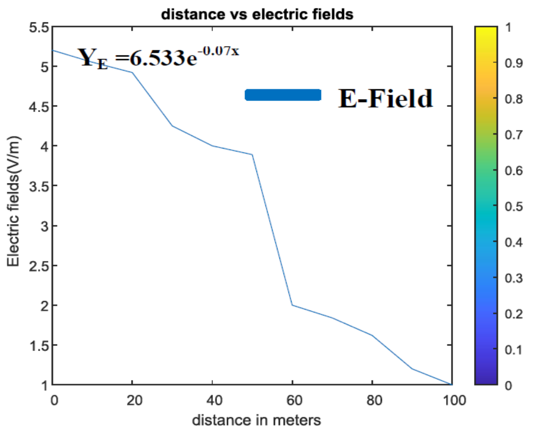


Figure 3a: Graph of the Electric fields from 132Kv power transmission lines at University of Ibadan as a function of horizontal distance.

$Y_M= 7.279e^{-0.023X}$ from this function, Y_M is the magnetic field and X is the horizontal distance from the foot of the power transmission line. Thus, at 25m (RoW for 330Kv) the magnetic field will be (4.10μT), which is about 0.82 % for public and 0.41% occupational of the ICNIRP data recommended value.

$Y_E=6.533e^{-0.07X}$ from this function, Y_E is the Electric field and X is the horizontal distance from the foot of the power transmission line. Thus, at 10m (RoW for 132Kv) the electrical field will be 3.24V/m which is about 0.65 % of the ICNIRP data recommended value.

Figure 3b: Graph of the Magnetic fields from 132Kv power transmission lines at the University of Ibadan as a function of horizontal distance.

$Y_M=6.557e^{-0.02X}$ from this function, Y_M is the magnetic field and X is the horizontal distance from the foot of the power transmission line. Thus, at 10m (RoW for 132Kv) the magnetic fields is 5.36μT, which is about 0.54% of the ICNIRP data recommended value.

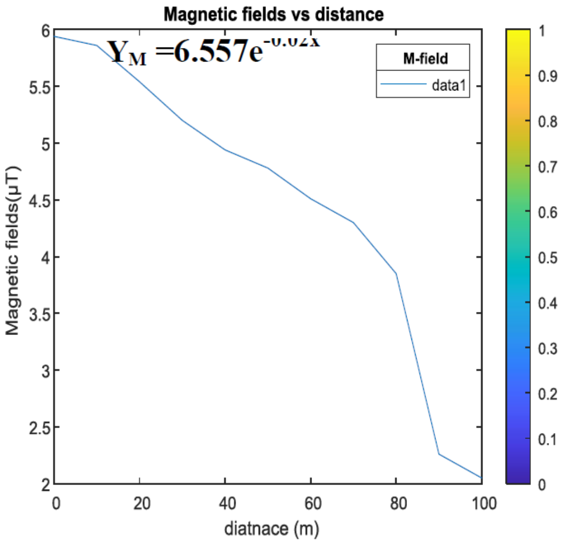
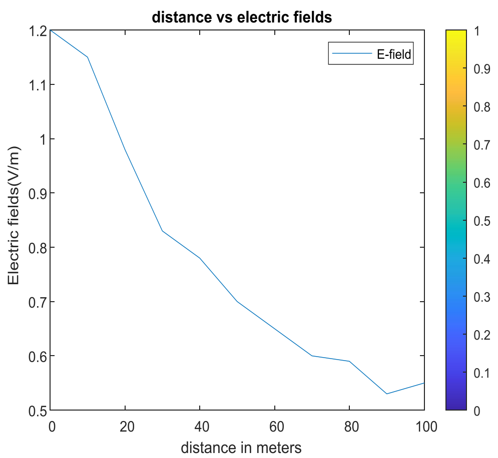


Figure 4a: Graph of the Electric fields from 33Kv power transmission lines at Shasha community as a function of horizontal distance.



$Y_E = 1.200e^{-0.006X}$ so that the field at10m (RoWfor33KV), is about 1.11V/m, which compare to ICNIRP 2010 value of 5Kv/m is about 0.02% of the ICNIRP data.

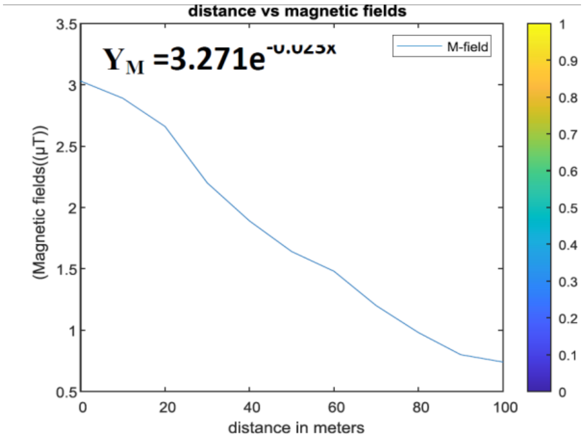


Figure 4b: Graph of the Magnetic fields from 33Kv power transmission lines at Shasha Ojoo as a functional distance.

The graph shows the magnetic field
$Y_M = 3.271e^{-0.023X}$, so that at 10m distance (X) the magnetic field will be about 2.59µT which compare to the ICNIRP2010 value of 200µT,is about 0.26% of the ICNIRP data.

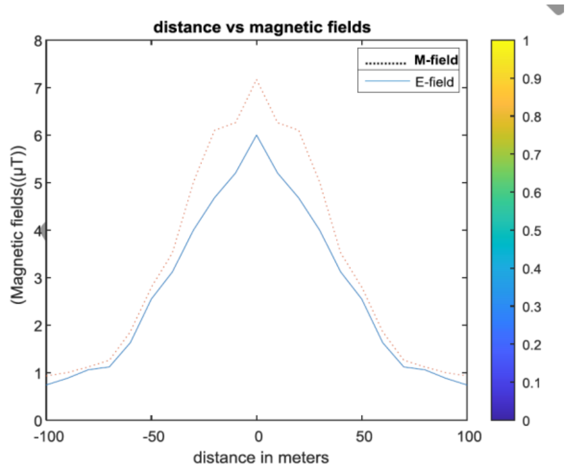


Figure 5: A graph of Magnetic fields generated under powerlines.

The distribution of magnetic induction in 1m above the ground level under a three-phase high voltage transmission line.the magnetic field created by 330Kv overhead power line has been obtained.

Comparison

It's obvious that the maximum values of magnetic fields which is represented by dotted lines reach on the axis of the line is 7.17 µT. These values are in line with international standards. It is also observed that this value could be influenced by external factors like an electrical wire and other sources of electrical appliances around the site of measurement. It is also observed that at the highest value under the middle phase conductor at the center point of the power line decreases rapidly with thelateral distance increases, it decreases as one increases the distance from the center point of the transmission line corridor to achievevery negligible values far from the power line center, It has also been found that the shape of the graph depends on several factors, such as the load current, the height of conductors, the spacing between two adjacent conductors observation point height above the ground and the phase configuration of the circuit lines, horizontal, vertical, triangular or inverted triangular line, the horizontal configuration generates the high magnetic induction values due to all conductrs being near to the ground level, on the other hand, the inverted triangular configuration producesthe lowest magnetic inductiono values. the magnetic flux density at a height of 1m above the ground under an overhead power line with a current amplitude of 1000A does not exceed 20µT for lines higher than 10m, which is five times lower than the public reference value proposed by the ICNIRP.

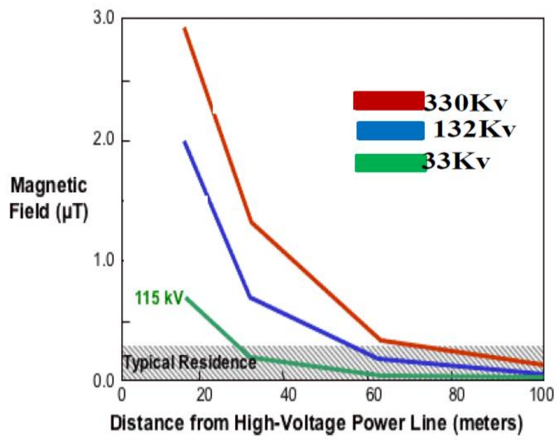


Figure 6

Comparison:

The result above clearly shows that the highest measured value of the magnetic field is less than ICNIRP data by about 92.8%, which means that the lines posed no magnetic field threat. The highest measured electric field is about 98.8% less than the ICNIRP data from 330KV power line, this shows that no electric field threats from the power lines.

Exposure characteristic	**Frequency range**	**Magnetic field(µH)**	**The magnetic fieldat50Hz(mG)**
Occupational exposure	0.025–0.82kHz	25/ f	5000
General publicexposure	0.025 – 0.82kHz	5/ f	1000

Table2. Reference levels of magnetic field exposure[6].

2.3. National standards

To safeguard the people from electromagnetic fields, many European countries have already established national regulations or guidelines. However, in many cases, separate standards bodies have created standards-based on slightly diverse emphasis and interpretations of the same concept. The EMF exposure limits in-country regulations range greatly from international guidelines. Some Eastern European standards, which emphasize low-level thermal impacts, cannot easily be harmonized with current Western standards because of this. Some Eastern and Western European countries have EMF exposure limit values that differ by more than 100 times.

Location	Date	Chronic exposure limit	Exposure Limit (mG/µT)
ICNIR*P*[b]	1998		1000 mG or 1G 100 µT /
Switzerlandb	1999	Limit magnetic fields near homes, apartments, schools, hospitals, playgrounds based on the maximum rated current of the power line. /	10 mG 1 µT
Italy*[b]*	1999	Regulations limiting magnetic fields near nurseries, schools, hospitals, and homes, where people spend more than 4h per da//	2.0 mG 0.2 T
Netherlandsb	2005	Requires distance between power lines and places children spend significant time to limit average exposures /	4.0 mG 0.4 µT

**Table 3. Exposure limits for magnetic fields from power lines and substations in some countries.
A Source: ICNIRP 1998 b Source: WHO Report 2007.**

Different standards that define the maximum permissible exposure levels for electromagnetic exist for example by those from ICNIRP. To avoid health and safety risks, standards limiting the maximum levels of EM radiation in the vicinity of power lines have been established and are strictly adhered to.

2.3 Regulatory Agencies

To assess the allowable exposure limit of humans to magnetic and electrical fields, the responsible regulatory bodies have laid out standards and technical specifications [7]. The majority of regulatory agencies have contributed to the development of this standard. The International Commission on Non-Ionizing Radiation Protection [4], the Council for European Union [6], the World Health Organization [3], Oyo State Urban and Regional Planning (OSURP), PHCN [9], and the Institute of Electronics and Electrical Engineers [8], among others, have recommended permissible limits to electric and magnetic field exposure.

2.4 EM radiation

There has always been a concern about the effects of EM radiation from power lines (PLR), both on the utility staff, working under the lines, and on people living or working close to the lines.

2.5 Effects of EM radiation

Power line EMF has been classified as extremely low frequency (ELF) radiation. The lower the frequency, The longer the wavelength. In the 1970s many scientists believed that ELF electromagnetic radiation could not possibly have any biological effects, damaging or otherwise, because it was thought that the long-wavelength would prevent its interaction with a relatively small body, such as a human being. (The wavelength of a 50 Hz power wave is 6000 km).

III. RESULT AND DISCUSSION

In this study, the magnitudes of ELF radiation from round 330Kv, 132Kv, and 33Kv transmission lines have been analyzed for general public exposure using guidelines by ICNIRP, 2010 and WHO reference levels assessed using the Holaday HI-3604 survey meter to determine the safe zone for human activities, structures, and animals at different locations in Ibadan, Oyo State, Nigeria. The assessment was based on twocases, namely: 1. The highest measured value of the magnetic field is less than ICNIRP data by about 92.8%, which means that the 330Kv line poses no magnetic field hazard. The highest measured electric field is about 98.8% less than the ICNIRP data from the 330KV power line, indicating no electric field hazard from the power line. The results of the measured data also show that the values of the electric and magnetic fields at the right of way (RoW) distances of 25m for 330KV power lines as stipulated by the Power Holding Company of Nigeria (PHCN) in Nigeria are well below the recommended values for the general public. For general public exposure, the highest measured electric and magnetic field values are about 0.82% and 0.58% respectively, as regards the ICNIRP guideline. Thus, electric and magnetic fields in Ibadan pose no health hazard to the general public and workers at PHCN RoW distances. Hence, with the increase in distance, the magnetic and electric field strengths are reduced. The overall results indicate that both the electric field and magnetic field posed by the transmission line were below standard. The ELF EMF present within the assessment area is generated mainly by the high voltage transmission line. This is in line with the study done by WHO [10,11]. Higher electric and magnetic field strengths were recorded at the area directly under the transmission lines. The report published by WHO supports this statement [10,11]. Despite the fact that both field strength values are less than the maximum permissible exposure for transmission lines, the general public is advised tokeep a safe distance from the transmission line to minimize their exposure to an electric and magnetic field.

IV.CONCLUSION AND RECOMMENDATIONS

This study presents measurement and assessment of a safety distance from transmission lines and evaluates it by comparing it with ICNIRP and WHO exposure limits for the general public and also occupational exposure levels. From the magnetic field graph above, electric field and magnetic field measurements at the base of the transmission line were made and the values obtained were recorded, Figure 1, Figure 2, and Figure 3, respectively. The magnetic field of the lateral line of the transmission line (TL) is dense at a high-value of 7.17uT as shown in Figure 1,but it is below the guideline (about 100 μT) specified by ICNIRP. This means that the inhabitants/people close to the power line are exposed to a higher magnetic field range. According to the PHCN standard (about 42%), proximity disability is higher. It is hereby estimated from the results above that houses located 300 ft away from the 330KV power transmission line and above are safe for residents and any human activities, while those below 300 ft are not safe for residence. This survey eventually turned out that many homes violated the minimum safe distance from the building to the power lines. This study also suggests that dwellers should avoid using under transmission lines as a playing ground for leisure, shops for business, or social gatherings.

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