Original Research Article

Evaluation of Electromagnetic Fields from Power Lines in Irrua, Edo State, Nigeria

Abstract

There have been a lot of scientific discords on the effects of electromagnetic fields along electric power lines for close to four decades now. These fields are concentrated close to the power lines and fall with distance. The magnetic fields vary as the load on the power lines changes while the electric fields remain approximately constant. Electric power lines produce large amount of extremely low frequency electromagnetic fields. This research gives an analysis of electromagnetic fields emitted by 330 kV electric power lines in Idumebo Community, Irrua, Esan Central Local Government Area of Edo State, Nigeria. The measurements results obtained (using ED78S Electrosmog meter) were compared with the international standard threshold values. The results show that the magnetic field only exceeded the threshold value at the public areas while the electric field at all points is still below the limit as recommended by International Commission of Non-Ionizing Radiation Protection (ICNIRP) and other standard regulatory bodies. We also recommend some practical precautionary measures to extremely low frequency electromagnetic fields.

Keywords: Electromagnetic Fields, Extremely Low Frequency, Threshold Values, Electric Power Lines, Radiation

1. Introduction

Electric power transmission lines are considered to be one of the major sources of electromagnetic field which are created by electricity passing through a conductor. The availability of electricity is an essential ingredient in our environment. Provisions of constant electricity improve the standardization of the well-being in a society. The electricity distribution from one region to another depends on network of cables, sited underground and suspended from large metal structures known as pylons.The underground systems are not mostly used in electric power transmission in this part of the world because of some obvious disadvantages, though overhead systems also have their disadvantages [1, 2].

The transmission and distribution stages are very important to Electric power system because without these stages the generated power cannot get to the final consumers [3]. Electricity is generated at power stations and distributed around the country through the High Voltage Electricity Transmission Lines (HVETLs) [4]. The Nigerian transmission network comprises of over 11000 km of transmission lines (over 5000 km of 330 kV transmission lines and 6000 km of 132 kV transmission lines) among which about 24000 km of 33 kV sub-transmission lines and 19000 km of 11 kV distribution lines together with 22500 substations all over the country [5]. Electric power lines at frequency of 50 Hz or 60 Hz are the prominent source of Electromagnetic Fields of Extremely Low Frequency (ELF) [3]. Electromagnetic Fields (EMFs) and waves are the main media that carry signals and electrons from a certain source to the desired destination. The EMFs are propagating at the speed of light in free space (2.998×10^8 m/s) so it can be modulated, transmitted and received while conveying the necessary information. These electromagnetic waves consist of electric fields perpendicular to the magnetic fields and both are perpendicular to the direction of propagation with the wavelength of the waves depending on the operating frequency [6].

2. Electromagnetic Radiations

Electromagnetic radiations are energies that are propagated through free space in the form of electromagnetic waves. They have properties in common with other forms of waves such as reflection, refraction, diffraction, and interference. However, it may be characterized by the frequency with which it varies over time or by its wavelength. Electromagnetic radiations, however, have particle-like properties in addition to those associated with wave motion. There are many sources of electromagnetic radiations; Natural and Man-made [7]. Based on this research work, electromagnetic radiations can be categorized into two groups:

- Ionizing Radiation and
- Non-ionizing Radiation

Ionizing radiation holds a great amount of energy to remove electrons and cause the matter to become ionized. Thus, higher frequency waves such as the X-rays and gamma-rays have ionizing radiation. However, lower frequency waves such as radio waves, do not have ionizing radiation and are grouped as non-ionizing ELF EMFs (Non-ionizing radiations) which are produced wherever electricity is generated, distributed or used. There is no doubt that ELF EMFs can have effects on the body if the fields are high enough. Specifically, external EMFs induce internal electric fields in the body tissue, which can interfere with the action of nerves [2, 8]. There is uncertainty as to the exact level of field required to produce these effects, but the threshold for observable induced-field effects on nerves from ELF EMFs is according to most advisory bodies, above 1000 μT and 50 kV/m [2, 8]. Electric fields below this level can also produce indirect effects such as micro shocks and contact currents due to surface charge effects as evidence has emerged over the last few decades. The question of whether or not ELF EMFs may cause adverse health effects on humans and his immediate environment has become a source of considerable scientific discord; it should however, be noted that, we are all exposed to different amounts of these fields at different times [2, 8]. Magnetic fields can produce electric fields and vice versa. With most types of radiation, the electric and magnetic fields are coupled; they act as one, they are considered together as EMFs. But with ELF radiation, the magnetic field and electrical field can exist and possibly act individually and so they are often and better studied separately [6].

A noticeable source of ELF EMFs radiation is the HVETLs which in some instances produce such high losses that they bend the Earth's ionosphere. HVETLs are dangerous because they are constantly losing energy; because we cannot see electricity and we do not use to have a detector so we cannot see it oozing. If we have an ELF spectrum analyser, we could find that ELF EMFs propagate very far, even at long distances and the intensity will be quite significant from biological viewpoint for long term exposures. Even for people living at distance from HVETLs, long term exposure may be dangerous. Often it was found that secondary transmission lines, like in the streets, are much worse polluters than the huge HVETLs [8]. The human body is a living antenna that can absorb and re-emit HVETLs energy in the environment. Animals also could contribute to re-enforcing environment electromagnetic loading. So a school full of children and teachers near HVETLs can become a tremendous new source of electrical energy and a major polluter, not only to the children in the school but even to people living nearby [8]. In the vicinity of transmission lines, the electric field, E and magnetic field, H are typically of the order of a few thousands of volts per metre (V/m) and a few hundreds of milligauss (mG), respectively. It has been confirmed that life is not safe under HVETLs. Apart from the consequence of electric shock that could happen, the magnetic field created around the wire by the flowing current can have adverse biological effects on human like neurological, cardiovascular disorders and low sperm count in the workers who regularly service the line [9, 10] . The influence of electromagnetic

radiation on biological matter is called Bio-electromagnetic which occurs when electric current is set up in tissues of a living organism which may lead to increase in body temperature as a result of energy deposition (which is the case for people living/working close to HVETLs as their body is immersed in the fields) causing biological effect. Internal electric and magnetic fields deposited in living organisms are evaluated using dosimetric calculation; any effect of electromagnetic energy on a body that is not heat related is referred to as athermal effect. This can equally result to health hazard. A biological effect is said to have occurred, when exposure to EMFs cause some significant or detectable physiological change in the biological system. These effects may occasionally lead to a detrimental health condition. The most widely accepted standard for Bio-eletromagnetic control was developed by the International Commission of Non-Ionizing Radiation Protection (ICNIRP), the Institution of Electrical and Electronics Engineers (IEEE) and the American National Standards Institute (ANSI). Protection against adverse health effects require that these basic restrictions are not exceeded [7, 11-12].

The International Radiation Protection Association (IRPA) and ICNIRP recommend that the electric field and the magnetic field strength should be measured for evaluation of electromagnetic radiations pollution from HVETLs [8].

Tab. 1: Recommended Limits for Electric and Magnetic Fields Strength [13]

Organization	Public Area		Occupational Area	
	E (V/m)	B (μT)	E (V/m)	B (μT)
ICNIRP	5	0.1	10	0.5
European Union	5	0.1	10	0.5

3. Theoretical Background

Electromagnetic radiations released are related to the temperature of the body. Stephan-Boltzmann law stated that if this body is a black body; one which perfectly absorbs and emits radiation, the radiation released is equal to the temperature raised to the fourth power. Therefore, as temperature increases, the amount of radiation released increases greatly. Bodies that release radiations will absorb radiations at certain wavelength which is related to temperature. As the temperature increases, the wavelength of maximum emission decreases.

Electromagnetic radiations which are form of energy are emitted and absorbed by body that act as a wave travelling through space are described in terms of its wavelength, frequency, or energy. All electromagnetic energy travels at the speed of light (c = 2.998×10^8 m/s), so wavelength (λ) and frequency (ν) are inversely related:

$$c = \lambda \nu \quad (1)$$

The relationship between wavelength and energy, E, is described by the equation:

$$E = \frac{hc}{\lambda} \quad (2)$$

Where h is Planck's constant ($h = 6.625\times10^{-34}$ Js) and c is the speed of light. Replacing the constants h and c with their respective values, Energy E becomes

$E = 1.986\times10^{-25}$ Jm

An inverse relationship exists; electromagnetic radiations with shorter wavelengths are more energetic. The relationship between energy and frequency is given by the equation:

$$E = h\nu \quad (3)$$

A direct relationship exists; electromagnetic radiations with a higher frequency are more energetic, major sources of ELF EMFs are the HVETLs. The lines can produce high losses that might bend the Earth's ionosphere. Interaction of Human body with electric and magnetic fields from HVETL exposure to HVETLs results in internal body currents and energy absorption in tissues as a result of thermo-molecular agitation. This depends on the coupling mechanisms, the frequency (f) and the electrical conductivity of the medium (σ) [14].

Radiated coupling occur when electromagnetic energies are emitted from a source which propagates to the far-field and induces voltage and current in another circuit. Unlike common impedance coupling, no conducted path is required. Unlike electric and magnetic field coupling, the victim circuit is not in the electromagnetic near field of the source. Radiated coupling is the only possible coupling mechanism when the source and victim circuits (including all connected conductors) are separated by many wavelengths. Of the four possible coupling mechanisms, radiation coupling is the one that seems to get the most attention. The idea that currents flowing in one circuit can induce currents in another circuit that is across the room or even miles away is fascinating to most of us. Maxwell's treatise on electromagnetism postulated the existence of electromagnetic waves back in 1864. He was able to calculate the velocity of propagation of these waves, and describe wave reflection and diffraction. However, it was twenty five years later before anybody was able to verify the existence of Electromagnetic Waves. Practical transmitters and receivers were not developed until the beginning of the 20th century. People viewed electromagnetic radiation as something nearly magical. The theory was difficult to comprehend and the equipment required to transmit and receive signals was fairly complicated. The more difficult challenge for the designers of most electronic products is to design circuits that do not produce too much electromagnetic radiation. In order to understand how and why circuits exhibit unintentional electromagnetic emissions, it is helpful to review a few general concepts related to electromagnetic radiation [14].

4. Materials and Method

To measure the fields from the electric power line sensor ED78S electrosmog meter which detects low frequency (LF) magnetic field in units of tesla or gauss, electric field in unit of V/m and high frequency RF EMF strength signal was used. It also measured LF magnetic field strength which is shown on the digital LCD display (with μT and mG). Two LF modes can be selected;

(a) LF30 mode (0.1 mG-30 mG) and

(b) LF 600 mode (1 mG – 600 G).

It runs on an alkaline battery (9 volts) and measuring tape to measure distances. The study areas were selected base on the local HVTPLs distribution. We took measurements (5 m, 10 m, 15 m, 20 m, …100 m) of electric and magnetic fields at selected locations along preferred route. Both electric fields and magnetic fields were measured. Each measurement was acquired over a short period. Upon stabilization of a reading, the average value was recorded. Continuous measurements were performed at different distances at each measuring points. The measurements were taken at a height of 1.5 m above sea level. The electric field was measured in units of V/m and the magnetic field was measured in units of μT. This instrument meets the Institute of Electrical and Electronic Engineering (IEEE) instrumentation standard for obtaining valid and accurate field measurements at HVTPLs frequencies (IEEE Std. 1308 – 1994, R2001, R2010). Measurements of electric field and magnetic fields were taken horizontally on the preferred Route along a 330kv transmission line that runs through the power lines at Idumebo area (around Irrua Specialist Teaching Hospital) Irrua, Edo State, Nigeria.

5. Results and Discussion

Tabulated results of the measurements are presented in Tab. 2 also in Fig.1

Tab.2: Measured Values of Electric and Magnetic Fields at 330 kV HVETLs in Irrua

Distance (m)	Mean Electric Field (V/m)	Mean Magnetic Field, B (μT)
5	0.75	0.49
10	0.72	0.47
15	0.67	0.45
20	0.63	0.41
25	0.58	0.37
30	0.55	0.36
35	0.52	0.30
40	0.50	0.28
45	0.48	0.27
50	0.43	0.27
55	0.41	0.21
60	0.40	0.18
65	0.38	0.15
70	0.37	0.12
75	0.35	0.10
80	0.33	0.09

85	0.31	0.07
90	0.30	0.06
95	0.30	0.05
100	0.29	0.05

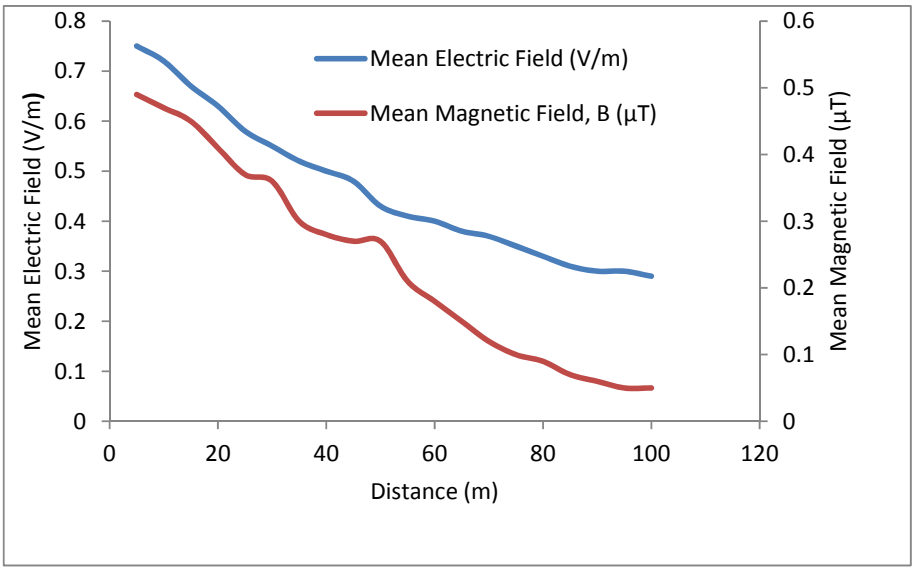

Fig. 1: Plot of Electric and Magnetic Fields strength at 330 kV HVETLs in Irrua

Tab. 2 show the measurements from the 330 kV HVETLs and Fig.1 show the graphical representation of the electric and magnetic field measurements at distance of 5m to 100m at an interval of 5m around the HVETLs in Idumebo Community Irrua, Edo State, Nigeria. The lowest and highest electric fields measured were 0.29 V/m (100 m) and 7.5 V/m (5 m) while that of the magnetic fields were 0.05 µT (100m) and 0.49 µT (5 m) respectively.

The results show that the magnetic field only exceeded the threshold value at the public area (around Irrua Specialist Teaching Hospital) while the Electric Field at all points; both at the occupational and public areas is still below the limit as recommended by International Commission of Non-Ionizing Radiation Protection (ICNIRP) and other standard regulatory bodies.

It was also observed that the Right of Way as recommended by Power Holding Company of Nigeria (PHCN), Environmental Standards and Regulations Enforcement Agency (NESREA) and other local and international regulatory bodies both for residential (occupational) and commercial (public) structure were within the recommended limit.

6. Conclusion and Recommendations

The measurement of Electric and Magnetic fields from the 330 kV HVETLs at Idumebo Community Community, Irrua, Esan Central L.G.A., Edo State, Nigeria have been carried out using ED78S Electrosmog meter. This was done in other to ascertain and evaluate the

amount of electromagnetic radiations from these HVETLs. The obtained results were compared with the international standards and guidelines exposure limits which are set by ICNIRP and other standard regulatory bodies.

The analytical results show that the electric field is below the standard threshold limit and do not pose any risk to human health if the exposure is for short period, however, there might be some element of risk if the exposure is for a continuous and long period. The magnetic field results on the other hand, exceeded the standard threshold values at some areas (public areas; Irrua Specialist Teaching Hospital premises) and this of course might constitute a threat to human lives in particular. Scientific knowledge about the health effects of ELF EMFs is based on a large number of technological, epidemiological, animal and environmental studies. Many outcomes have been examined but so far no conclusive evidence or connection has been drawn, further research still need to be done [2, 13, 15].

It was also observed from Fig. 1 that where as there were drop in electric field, there were also drop in the magnetic field as the distance increase from the HVETLs simultaneously. Hence, there was a good correlation between electric field and magnetic field and that the Right of Way both for the public and occupational areas was within the recommended limit in the study area.

Based on the results of the measurements, analysis and evaluation of this research we therefore, make the following recommendations:

- Members of the public should be provided with more information about exposures and the mechanism they could take on their own to mitigate exposures to ELF EMFs.

- Environmental Standards and Regulations Enforcement Agency (NESREA) and other responsible agencies should as a matter of urgency rethink the need for precautionary measures regarding the exposure of people to ELF EMFs.

- Buildings of any kind either residential or commercial should be stop within specified and recommended distances from power lines.

- Electricity companies should be encouraged to choose the optimal phasing (usually transposed phasing) for all new power lines and also be encouraged to convert existing power lines where possible and justifiable.

- Further research should be carried to find out why the magnetic field exceeded the recommended threshold values even when the recommended distance were maintained and to compare outdoor and indoor signal to clarify whether it is safe to stay indoors compared to outdoor.

- Measurements, analysis and evaluation of electromagnetic fields from power lines should be carried out in other parts of the country for risk management and comparative analysis.

7. References

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