Investigation of Electromagnetic Radiation from CRUTECH Electric Power Substation

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Abstract- The aim of this study is to empirically quantify the electric field intensity and the associated magnetic field strength emitted from an injection sub-station and compare results with the generally accepted safety standards such as the International Committee for Non-Ionization Radio Protection (ICNIRP) Standards. For the purpose of this study, We adopted the method of obtaining measurements using appropriate Instrumentation and Employing computational capabilities in order to simulate the propagation environment for easy analysis. MUSTOOL (MT525) Electromagnetic radiation meter a portable field survey instrument that conforms to international standards was used. The switch yard was modelled as a rectangular box, while measurements were taken at specific locations around the box. These locations were sixty in number each having their corresponding x and y axes. At each point, measurements were obtained at three different heights of 1m, 1.5m and 1.75m at each point. But preliminary measurements showed that the Electric field was constant at all these heights. The magnetic field strength measured at a height of 1.5m, 1m, and 1.75m, had a maximum value of 54μT, 57.699μT, and 29.93μT, respectively. The Electric field intensity measured at a height of 1.5m peaked at 0.293kV/m. Contour plots show areas of interest in this investigation. It was noticed that the contour lines increases inwards. This indicates a buildup of magnetic field or electric field at these areas of interest. This was further buttressed by the surface plots, which highlights these areas of interest as elevations on the surface. When compared to the generally acceptable safety standard for public and occupational exposure to power-frequency EMFs. These values were less and within the limit recommended by International Commission on Non-Ionizing Radiation Protection (ICNIRP).

Indexed Terms- Electromagnetic Radiation, Electric Field, Magnetic Field

I. INTRODUCTION

The quantification of electric field strength and its associated magnetic field intensity radiated from injection sub-stations in Calabar, panacea health and environmental effects are subjects of the ongoing research. Radiation is the emission of streams of particles such as electrons, protons, high energy photons or an emission of a combination of these; each particle contains a certain amount of energy, which increases with growing frequency. This energy spreads out as it moves. Instead of producing charged ions when passing through matter, the electromagnetic radiation has sufficient energy only for excitation, the movement of an electron to a higher energy state They include radio waves, microwaves, infrared, visible light and the ultraviolet rays. In a study conducted in the city of Mashhad, Iran by [1], which involved the measurement of ELF-EMF levels at 10 different locations near power substations. The results of the study showed that the ELF-EMF levels at all 10 locations were below the international safety guidelines. The study had a number of merits which are, Firstly, it methodology, which means that the results are more likely to be representative of the ELF-EMF levels that people are exposed to in everyday life and the accuracy of the results. Finally, the study compared the results to international safety guidelines, which provided a context for understanding the significance of the findings. One of the limitation of the study was that it was only conducted in a single city. It is possible that the results would be different in other cities, with different power substations and different environmental conditions. Another limitation of the study was that it did not measure the long-term health effects of ELF-EMF exposure. Overall, the study provided valuable information about the ELF-EMF levels due to power substations in an urban environment. The results of the study suggest that the ELF-EMF levels in Mashhad, Iran, are below the international safety guidelines. Similarly, a study of the electromagnetic environment from a 750 kV transformer substation in Gansu Province, China by [2] involved the measurement of electric field intensity, magnetic field intensity, and noise at different locations around the substation. The results of the study showed that the electric field intensity and magnetic field intensity were highest near the circuit breaker and switchgear equipment. The noise levels were highest near the reactor and transformer equipment. Consequently, it merits and demerits were similar to that of [1]. Further studies conducted by [3] in Malaysia had a different scope in that the measurement of ELF EMF levels was at various locations in each residence. The results of the study showed that the ELF EMF levels in all three residences were below the international safety guidelines. However, the levels were highest in the owner-occupied house, and lowest in the under construction condominium. They suggested that it was because the owner-occupied house had more electrical appliances and wiring than the other two residences. Its merits and demerits were similar to studies conducted by [1] and [2]. In a more recent study by [4] in Nigeria, which involved the measurement of magnetic field levels at different locations around common home electrical appliances, such as refrigerators, televisions, and microwave ovens, the results showed that the magnetic field levels from common home electrical appliances can vary significantly depending on the appliance and the distance from the appliance. They used the results of the measurements to assess the exposure of people to magnetic fields from common home electrical appliances. He found that the exposure of people to magnetic fields from common home electrical appliances is generally below the international safety guidelines. However, he also found that some people, such as those who spend a lot of time near electrical appliances, may be exposed to magnetic fields that exceed the safety guidelines. They concluded by discussing the implications of his findings for public health. He notes that the long-term health effects of exposure to magnetic fields are still being studied, but that there is some evidence that exposure to high levels of magnetic fields may be associated with an increased risk of certain health problems, such as cancer. [5] discussed the need for a remote and safe monitoring system for magnetic fields produced by transmission lines in areas of high concentration of lightning strokes. The authors argued that such a system is necessary to protect workers and residents from the potential health risks associated with exposure to magnetic fields. The also described a prototype system that they had developed for remote and safe monitoring of magnetic fields. The system uses a magnetic field sensor to measure the field strength at a safe distance from the transmission lines. The data is then transmitted to a central computer for analysis. They evaluated the performance of their prototype system in a field trial. They found that the system was able to accurately measure magnetic field strength at distances of up to 100 meters from the transmission lines. The system was also able to detect changes in magnetic field strength caused by lightning strikes. A recent study showed that when people used a cell phone for 50 minutes, brain tissues on the same side of the head as the phone ‘s antenna metabolized more glucose than did tissues on the opposite side of the brain. Inhabitants living near mobile phone base stations suffered from frequent headaches, memory changes, dizziness, tremors, depressive syndrome and sleep disturbance [6]. [7] investigated electromagnetic radiations at high frequencies in order to assess its level of impact on the environment especially as it concerns the pulsed signal at microwave frequencies. They also offered some perspectives on the potential implications for human health exposure on the radiation should it exposure limit exceed the recommended safety zone of about 300 meters away from the base stations. They employed two measurement procedures; one for determining the power density due to the base station of interest, the other for evaluating the total exposure within the university environment. The maximum level recorded at the various sites was 1.3 mW/m2 while the total sum of radiation level encountered was about 2 mW/m2. The investigated level was compared with the international safety level and was found to be below the recommended safety level as provided by international agencies such as ICNIRP and ANSI as examples.

The proliferation of power transformers on our street is common practice. There are few literatures on the EMR from injection sub-stations in our locality compared to the volumes that exist for Cellular Base station. Thus, this study seeks to bridge this gap by empirically quantifying its characteristics. Also, this study seeks to buttress the need for individuals to adhere to stipulated guidelines or policies while procuring land or properties closed to injection sub-stations by diligently carrying out this study, the gravely effect of these EMR will be highlighted.

II. METHODOLOGY

2.1 Study area

The study was carried out in an injection sub-station in Calabar south local government area of cross river state. It is called Crutech injection sub-station rated 33KV/11KV. It comprised of two 7.5MVA power transformers called Anatigha and Crutech feeders. It was constructed with the aim of servicing Anatigha and the state owed University (CRUTECH).

Fig 2.1: Study Area at CRUTECH Injection Substation

2.2 Modelling the Study Area

The substation and its environment was modeled as a set concentric rectangles, such that the switch yard was located in the inner rectangle.

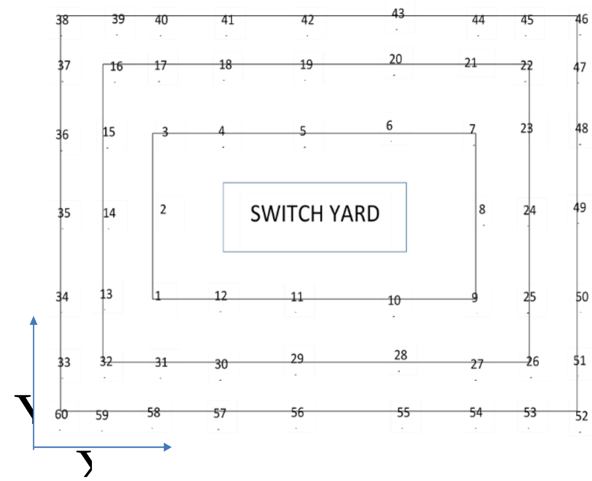

Fig 2.2: Modelled switchyard

2.3 Objective Measurements

Measurements were taken at specific distances away from the switch yard at three (3) different heights of 1m, 1.5m and 1.75m.. These locations were sixty in number each having their corresponding x and y axes. The methodology adopted was the broadband measurement technique. The MUSTOOL MT525 Electromagnetic radiation meter which is a portable field survey instrument that conforms with international standards such as GB8702-1988 regulation for electromagnetic radiation protection, HJ/T 10.3-1996 Environmental Impact Assessment Methods and Standard on Electromagnetic radiation and GB9175-88 Hygienic Standard for Environmental Electromagnetic waves was used.

III. RESULTS AND DISCUSSION

3.1 Results

Preliminary measurements showed that the Electric field was constant at all these heights traversing either the X or Y axis, however, the magnetic field strength varies at the different height. Hence, the magnetic field strength was measured at this three (3) heights along the X and Y axis.

3.2 Surface and contour plots

Figures 3.1, 3.2 and 3.3 shows surface plots of magnetic field strength at a height of 1.5m, 1m and 1.75m respectively. While Figure 3.4 shows the surface plot of the electric field intensity. These plots show areas of interest as elevated pyramids; the spikes show areas of concern which are indications of elevated levels. The flat surfaces show areas of constant radiation. Figures 3.5, 3.6 and 3.7 show contour plots of the magnetic field strength at a height of 1.5m, 1m and 1.75m respectively. While Figure 3.8 shows contour plot of the electric field intensity. These plots show a build-up of magnetic field and electric field in specific areas of interest shown in yellow.

Table 1. Magnetic Flux Density (μT) and Electric Field Intensity (KV/m) at different locations and heights

Location	X-Axis(m)	Y-Axis(m)	Magnetic Flux Density(μT)			Electric Field Intensity (KV/m)
			1.5m	1m	1.75m	
	-1.50	0.00	54.304	31.450	29.280	0.014
	- 1.50	1.00	45.720	57.699	25.176	0.030
	-1.50	2.00	34.570	42.892	20.186	0.035
	0.00	2.00	32.376	25.996	19.950	0.043
	1.5	2.00	24.263	17.139	12.050	0.164
	3.00	2.00	14.897	12.056	8.436	0.055
	5.00	2.00	14.613	10.391	6.990	0.043
	5.00	1.00	12.607	7.305	5.980	0.060
	5.00	0.00	10.954	5.386	5.168	0.040
	3.00	0.00	15.492	16.120	13.824	0.035
	1.5	0.00	29.644	20.174	11.555	0.085
	0.00	0.00	42.801	23.758	16.356	0.019
	-3.00	0.00	36.464	31.247	18.128	0.010
	-3 .00	1.00	23.644	27.750	14.052	0.016
	-3 .00	2.00	18.246	16.935	13.248	0.020
	-3.00	3.00	12.736	9.756	8.687	0.350
	-1.50	3.00	21.256	15.777	12.698	0.352
	0.00	3.00	28.514	19.490	16.365	0.028
	1.5	3.00	16.942	12.804	7.790	0.080
	3.00	3.00	10.087	8.865	5.242	0.035
	5.00	3.00	7.542	6.001	4.685	0.023
	6.00	3.00	5.658	4.745	3.562	0.235
	6.00	2.00	9.565	8.029	5.775	0.028
	6.00	1.00	7.147	5.615	4.315	0.030
	6.00	0.00	5.822	3.085	3.951	0.025
	6.00	-1.00	3.000	3.908	3.756	0.026
	5.00	-1.00	5.362	5.632	5.000	0.030
	3.00	-1.00	12.516	13.922	10.705	0.020
	1.5	-1.00	19.886	15.828	8.827	0.030
	0.00	-1.00	28.296	24.655	12.920	0.010
	-1.50	-1.00	22.758	19.653	10.956	0.015
	-3.00	-1.00	18.652	14.563	7.845	0.012
	-5.00	-1.00	14.65	10.654	6.564	0.012
	-5.00	0.00	26.731	19.381	12.185	0.011

-5.00	1.00	19.980	15.350	11.910	0.010
-5.00	2.00	12.378	11.274	9.460	0.001
-5.00	3.00	7.652	9.685	8.897	0.001
-5.00	5.00	3.333	7.666	3.265	0.001
-3.00	5.00	4.854	6.859	7.596	0.001
-1.5	5.00	10.444	12.458	8.152	0.001
0.00	5.00	16.125	16.143	10.628	0.020
1.5	5.00	10.777	8.286	5.125	0.047
3.00	5.00	7.826	5.842	3.850	0.035
5.00	5.00	4.156	3.865	3.215	0.030
6.00	5.00	3.768	3.665	2.879	0.025
7.00	5.00	3.200	3.497	2.126	0.022
7.00	3.00	4.258	3.263	2.664	0.022
7.00	2.00	5.895	5.148	3.011	0.020
7.00	1.00	4.158	3.397	2.276	0.020
7.00	0.00	3.028	3.189	3.095	0.014
7.00	-1.00	3.264	3.258	3.542	0.012
7.00	-3.00	3.011	2.895	2.658	0.012
6.00	-3.00	3.276	3.158	3.565	0.011
5.00	-3.00	3.095	3.028	3.542	0.010
3.00	-3.00	7.386	8.090	6.005	0.015
1.5	-3.00	10.013	12.072	8.493	0.020
0.00	-3.00	16.802	16.652	11.515	0.010
-1.50	-3.00	10.542	9.658	7.095	0.012
-3.00	-3.00	7.542	5.565	4.542	0.012
-5.00	-3.00	3.658	3.542	2.658	0.011

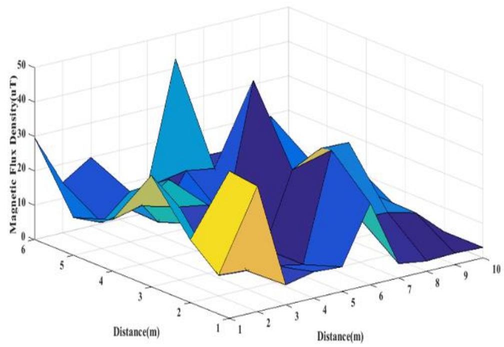

Fig. 3.1: Surface plot of the magnetic flux density at a height of 1.5m

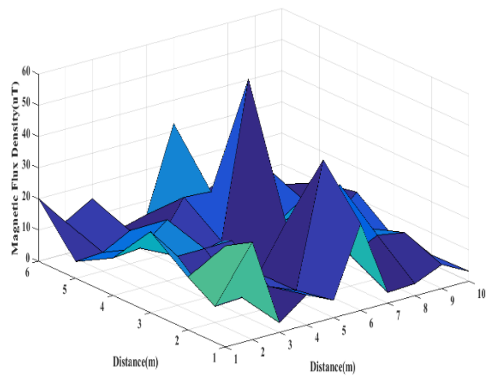

Fig. 3.2: Surface plot of the magnetic flux density at a height of 1m

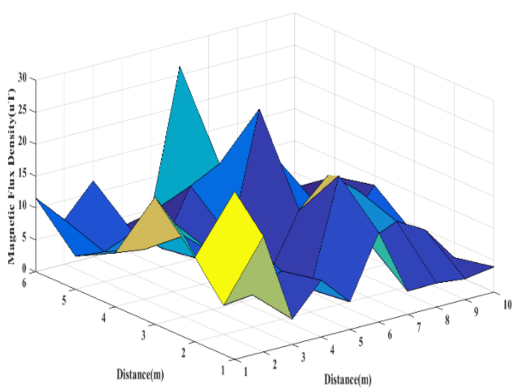

Fig. 3.3: Surface plot of the magnetic flux density at a height of 1.75m

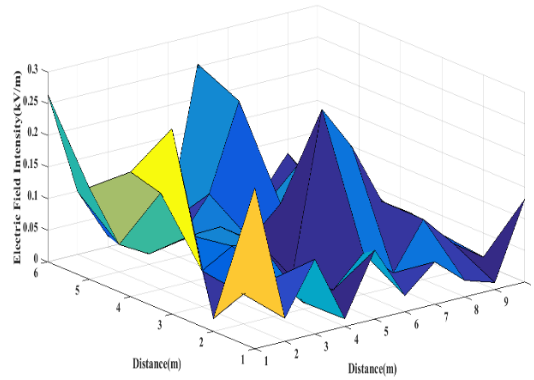

Fig. 3.4: Surface plot of the electric field at a height of 1.5m

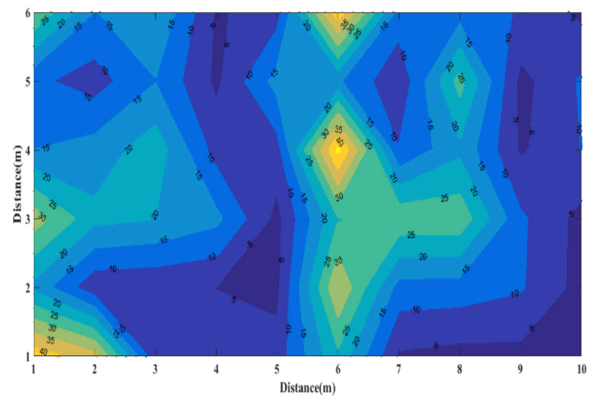

Fig. 3.5: Contour plot of the magnetic flux density at a height of 1.5m

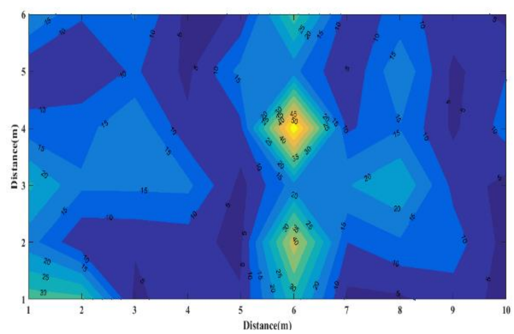

Fig. 3.6: Contour plot of the magnetic flux density at a height of 1m

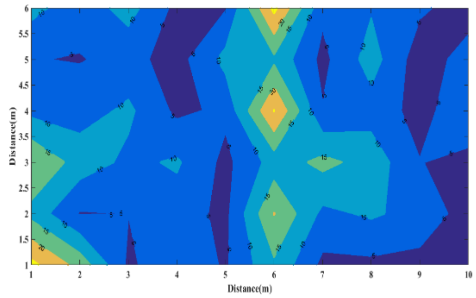

Fig. 3.7: Contour plot of the magnetic flux density at a height of 1.75m

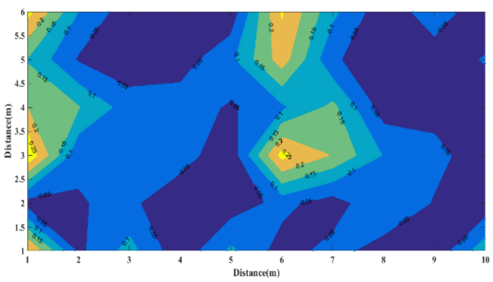

Fig. 3.8: Contour plot of the electric field at a height of 1.5m

3.3 Discussion

It was noticed that all the measurement took the form of a normal curve, the magnetic field strength measured at a height of 1.5m along the y-axis peaked when y was 0m except for values of x greater than 3 that peaked when y was 2m. When x was -5, -3, -1.5, 0, 1.5, 3, 5, 6 and the magnetic field strength measured at a height of 1.5m along the y-axis peaked 26.731μT, 36.464 μT ,54μT, 42.801 μT, 29.644 μT, 28.514 μT, 14.613 μT, 9.565 μT and 5.895 μT respectively. Its highest value was 54μT at x = -1.5m corresponding to measurement point 1, having a coordinate of x = -1.5 and y =0. The magnetic field strength measured at a height of 1m along the y-axis all peaked when y was 0m except for values of x equal to 5, 6 and 7 that peaked at y equal to 2m and x equal to -1.5 peaked at y =1. When x was -5, -3, -1.5, 0, 1.5, 3, 5,6 and 7 the magnetic field strength measured at a height of 1.5m along the y-axis peaked 19.381μT, 31.247μT, 57.699μT, 23.758μT, 20.174μT, 16.120μT, 10.391μT, 8.029μT and 5.148μT respectively. Its highest value was 57.699μT at x = -1.5m corresponding to measurement point 2, having a coordinate of x equal to -1.5 and y equal to 1. The magnetic field strength measured at a height of 1.75m along the y-axis all peaked when y was 0m except for values of x equal to 5, 6 and 7 that peaked at y equal to 2m and x equal to 1.5 peaked at y =1. When x was -5, -3, -1.5, 0, 1.5, 3, 5,6 and 7 the magnetic field strength measured at a height of 1.5m along the y-axis peaked 12.185μT, 18.128μT, 29.280μT, 16.356μT, 12.050μT, 13.824μT, 6.990μT, 5.775μT and 3.011μT respectively. Its highest value was 57.699μT at x = -1.5m corresponding to measurement point 1, having a coordinate of x = -1.5 and y =0.

The magnetic field strength measured at a height of 1.5m along the x-axis peaked when x was either -1.5m (for values of y equal to 0, 1, and 2) or 0m (for values of y equal to -3, -1, 3 and 5). When y was -3, -1, 0, 1, 2, 3, and 5 the magnetic field strength measured at a height of 1.5m along the y-axis peaked 16.802μT, 28.296μT, 54.304μT, 45.720μT, 34.570μT, 18.652 μT, and 14.65μT respectively. Its highest value was 54μT at x = -1.5m corresponding to measurement point 1, having a coordinate of x = -1.5 and y =0. The magnetic field strength measured at a height of 1m along the x-axis peaked when x was either -1.5m (for values of y equal to 1, and 2) or 0m (for values of y equal to -3, -1, 0, 3 and 5). When y was -3, -1, 0, 1, 2, 3, and 5 the magnetic field strength measured at a height of 1.5m along the y-axis peaked 16.652μT, 24.655μT, 23.758μT, 57.699μT, 42.892μT, 19.490 μT, and 16.143μT respectively. Its highest value was 57.699μT at x = -1.5m corresponding to measurement point 2, having a coordinate of x = -1.5 and y =1. The magnetic field strength measured at a height of 1.75m along the x-axis peaked when x was either -1.5m (for values of y equal to 0, and 1, 2) or 0m (for values of y equal to -3, -1, 3 and 5). Thus, when y was -3, -1, 0, 1, 2, 3, and 5 the magnetic field strength measured at a height of 1.75m along the y-axis peaked 11.515μT, 12.920μT, 29.280μT, 25.176μT, 20.186μT, 16.365μT, and 10.628μT respectively. Its highest value was 29.680μT at x = -1.5m corresponding to measurement point 2, having a coordinate of x = 0 and y =0.

As stated earlier, the electric field intensity at the three different heights were fairly constant. Hence, the Electric field intensity measured at a height of 1.5m along the y-axis peaked when y was 0m except for values of x equal to -1.5 and 0 that peaked when y was equal to 1m and 2m respectively. When x was -5, -3, -1.5, 0, 1.5, 3, 5, 6 and 7 the electric field intensity measured at a height of 1.5m along the y-axis peaked

0.024kV/m, 0.037kV/m, 0.088kV/m, 0.293kV/m, 0.265kV/m, 0.223 kV/m, 0.145 kV/m, 0.118 kV/m and 0.131 kV/m respectively. Its highest value was 0.293kV/m at x = 0m corresponding to measurement point 4, having a coordinate of x =0 and y =2.

The Electric field intensity measured at a height of 1.5m along the x-axis peaked when x was 0m except for y equal to 1 that peaked when x was equal to 5m respectively. When y was -3, -1, 0, 1, 2, 3, and 5 the electric field intensity measured at a height of 1.5m along the y-axis peaked 0.088kV/m, 0.096kV/m, 0.254kV/m, 0.112kV/m, 0.293kV/m, 0.194kV/m, and 0.073 kV/m respectively. Its highest value was 0.293 kV/m at x = 0m corresponding to measurement point 4, having a coordinate of x =0 and y =2.

The contour plots show areas of interest in this investigations, these areas of are shown in yellow. It is noticed that the contour lines increases inwards. This indicates a buildup of magnetic field or electric field at these areas of interest. These is further buttressed by the surface plots, which highlights these areas of interest as elevations on the surface.

Generally accepted guidelines have been established for safe public and occupational exposure to power-frequency EMFs. The reference levels for general public exposure are, according to the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines for the electric-field strength, magnetic field strength and magnetic flux density at 50Hz are 5kV/m, 100uA/m and 200uT respectively.

The measured electric-field strength values are in their entirety below the reference level for safe public and occupational exposure.

It can be seen that the measured magnetic field strength values were below the reference level for safe public and occupational exposure. Though significant difference was noted at different heights corresponding to the head, chest and groin areas.

So the measured field values are substantially within recognized guidelines, suggesting that these values are not dangerous and, therefore, are no cause for concern among the public or working personnel

CONCLUSION

Investigation of low frequency electric and magnetic fields and their interconnectivity are the main problems in transmission and distribution of power energy in terms of standardized electromagnetic radiation permissible and safety limits of human exposure.

This study presents investigation of low frequency electromagnetic radiation from Crutech electric power injection sub-station located in Calabar, Cross River state using a broadband measurement technique and the time average method. MUSTOOL MT525 Electromagnetic radiation meter a portable field survey instrument that conforms to international standards was used. The results presented as contour plots and surface plots shows that there was distinctive difference in the magnetic flux measurements at different heights of 1m, 1.5m and 1.75m. The electric field measurement was constant at these heights.

When comparing the measured values of the magnetic and electric fields to acceptable standard, it was observed that this values very within the acceptable range for occupational safety exposure.

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