THE NIGERIAN INSTITUTION OF PROFESSIONAL ENGINEERS AND SCIENTISTS

IN COLLABORATION WITH

NATIONAL CENTRE FOR ENERGY, ENERGY COMMISSION OF NIGERIA

PRESENTS

BOOK OF PROCEEDINGS

2nd International Conference

theme:

EMERGING TRENDS IN SCIENCE AND TECHNOLOGY

TOWARDS INDUSTRY 4.0 REVOLUTION

15TH – 17TH FEB 2023

9:00AM DAILY

VENUE: NATIONAL CENTER FOR ENERGY AND ENVIRONMENT, UNIVERSITY OF BENIN

CHIEF HOST
PROF. D.I. IGBINOMWANHIA
NCEE (ENERGY COMMISSION OF NIGERIA)
UNIBEN, BENIN CITY.

HOST
DR. O.O IGHODARO
CHIEF EXECUTIVE OFFICER NIPES

INTERNATIONAL KEYNOTE SPEAKER
DR. SHIVAN CHETTEY
Director, Biomedical Industrialisation & Globalization Division, Wits Health Consortium, South Africa

NATIONAL KEYNOTE SPEAKER
PROF. IKUOBASE EMOVON
Dean College Of Engineering, Federal University Of Petroleum Resources, Effurun, Delta State

NIPES-NCEE Conference Proceedings
The 2nd International Conference 15th-17th Feb. 2023
351-360
www.nipesjournals.org.ng

OCCUPATIONAL EXPOSURE LEVELS OF ELF MAGNETIC FIELD ASSESSMENT IN 330 KV SWITCHYARD OF HYDRO-PLANT AND GAS-PLANT STATIONS IN NORTH-CENTRAL NIGERIA

Ocheni, Abdullahi Ugbede Usman*[1, 2]; Oyedum, Onyedi David[2]; Nwohu, Mark Ndubuka[3]; Moses, Abiodun Stephen[2]

[1]Department of Physics, University of Maiduguri, Nigeria
[2]Department of Physics, Federal University of Technology, Minna
[3]Department of Electrical and Electronics Engineering, Federal University of Technology, Minna
Corresponding email: oauusman@unimaid.edu.ng

Abstract
The ardent quest for electricity that affects virtually all human activities has evolved the speculation of its adverse effect on human health when exposed to the associated electromagnetic field. Occupational exposure levels of the strength of extremely low frequency (ELF) magnetic field in five 330 kV switchyard of Hydro-plant and Gas-plant generation stations with similar infrastructures were investigated, assessed and analysed. The entire switchyard measurements of ELF magnetic field were performed with reference to three observation heights of 1.0, 1.5 and 1.8 m above ground level via spot measurements technique in segmented manner using Extech 480826 triple-axis EMF metre in conformity to IEEE standards, and occupational exposure computed from the mean of the three observation heights for each spot. The data obtained were subjected to analysis using One-way ANOVA SPSS package. The results demonstrated occupational significant differences of ($p < .001$) between 330 kV switchyards of Shiroro Hydro-plant and Geregu Phase II Gas-plant, significant differences of ($p = .045$) between switchyards of Geregu Phase I Gas-plant and Geregu Phase II Gas-plant, and also significant differences of ($p < .001$) in occupational exposure was demonstrated between switchyards of Jebba Hydro-plant, Kainji Hydro-plant when separately compared to Geregu Phase I and Geregu Phase II Gas-plants. However, non-significant differences occurred between switchyards of Shiroro Hydro-plant and Jebba Hydro-plant, Kainji Hydro-plant and Geregu Phase I Gas-plant, and Jebba Hydro-plant with Kainji Hydro-plant. This study has revealed the prevalence of electropollution in occupational environment and variation in the strength of ELF magnetic field between switchyards personnel might encountered at instant of the measurements.

1.0 Introduction
Electrical infrastructure, such as transmission lines, substations and its facilities are regarded as main sources of manmade extremely low frequency (ELF) magnetic field which are of high strength close to source [1]. These sources of radiated ELF magnetic field are known as electropollution [2] or electrosmog [3] and have contributed to the level of environmental pollution in the atmosphere, in which the modern society exists and develops [4]. In Nigeria, the operational frequency of generated electricity is 50 Hz, which lies in the range of extremely low frequency (3 – 300 Hz) [5]. The results from epidemiological surveys have established that the intensity of ELF magnetic field from manmade sources are in manifold higher when compared to the intensity of natural sources [6].

The strongest occupational exposure to extremely low frequency magnetic field that form the fundamental part of the operating mechanism can be found in work environments where electricity is generated, transmitted or distributed [7, 8]. The systems expectedly emit very high ELF magnetic fields, because of the magnitude of electric current that pass through the system [9].

These form part of the reasons why the average exposures of magnetic field in occupational environment are found to be greater in electric utility than in other occupations [10]. And since limited number of people are exposed to these fields due to professionalism [11], and the field limits in occupational environments stipulated safety regulations [12]. Therefore, there should be need to embark on assessment of ELF magnetic field strength in switchyards vicinity, compare strength and determine the level of exposure workforce encounter in their day-to-day task. Since ELF magnetic field cannot be easily screened by human body because of the resemblance of permeability in both air and skin. Therefore, the study was aimed at determining whether the magnitude of the emitted field lies within the occupational reference thresholds set by ICNIRP for environmental safety.

Evidences from epidemiological studies of people who live or work around electric power stations [13], have revealed that prolonged excessive exposure to extremely low frequency magnetic field induces electric field within the human body and if there exist potential differences within it causes a current to flow due to its conductive nature [14,10]. The biological effects appear to cause or promote certain forms of leukaemia and brain tumours [15]. In view of these, the wide usage of electricity and its associated appliances have raised the question of electropollution and health risk associated with it [16].

The International Agency for Research on Cancer (IARC) based on the evidence gathered from international research [17], has classified ELF magnetic fields into category 2B, corresponding to the category of agents that are "possibly carcinogenic to humans" [18], that might transform normal cells into cancer cells [19]. And to support the claim World Health Organisation (WHO) through the International EMF Project has established the International Commission on Non-Ionising Radiation Protection (ICNIRP) which releases periodically recommendations, and the present occupational reference level is set at 1 mT [7]. However, scientists of the International Electromagnetic Fields Alliance (IEMFA), advised nations of the globe should adopt lower exposure guidelines of 0.1 µT to guard current public health and that of future generations in order to reduced exposure limits of radiated electromagnetic fields from electrical power and telecommunications technologies [20].

In Nigeria, several studies on ELF magnetic field transmission lines environment have been carried out in recent times, thus, accenting the presence of extremely low frequency magnetic field. However, from published literatures it were observed that there are scarce studies on comparative analysis in the strength of ELF magnetic fields emission in switchyards of generating plant of the study areas. Therefore, it is noteworthy to embark on assessing the magnitude ELF magnetic field in the transmission switchyards using spot measurements technique to fill the existing research gap.

In this study, One-way analysis of variance (ANOVA) was used to analyse the significant differences for the strength of ELF magnetic field level in 330 kV of North-Central, Nigeria to determine whether the personnel performing their day-to-day task in each switchyard are exposed to the same environmental hazard within the vicinity.

Figure 1 indicate the study areas on map of Kogi and Niger State, Nigeria.

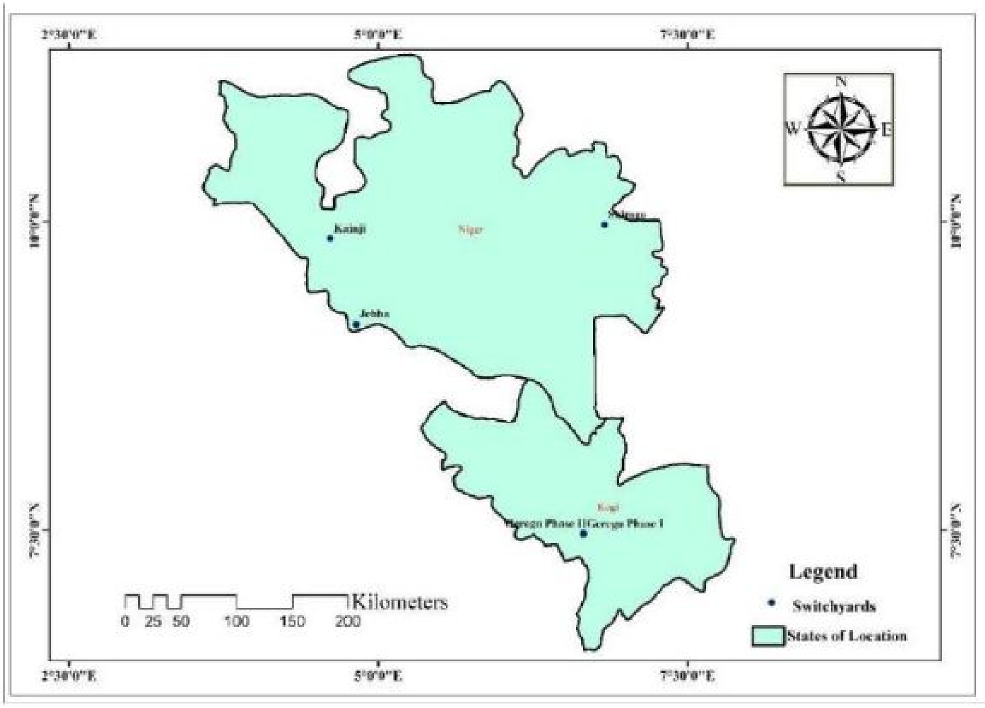

Figure 1: Map of the Study Areas

The studies were conducted in five 330 kV transmission switchyard stations. The stations are Geregu phase I switchyard at (7.470116ºN, 6.658052ºE) generation source from three gas turbines with installed capacity of 345 MW, Geregu phase II switchyard at (7.472133ºN, 6.659133ºE) generation source from three gas turbines with installed capacity of 507 MW both located in Kogi state while Kainji switchyard at (9.861044ºN, 4.613103ºE) generation source from eight turbines with installed capacity of 760 MW, Jebba switchyard at (9.168045ºN, 4.821214ºE) generation source from six turbines with installed capacity of 578 MW and Shiroro switchyard at (9.972474ºN, 6.830333ºE) generation source from four turbines with installed capacity of 600 MW all located in Niger state, Nigeria.

1.2 Governing laws of magnetostatic fields emission

The electric field and magnetic field produced by power facilities are usually uncoupled, due to the fact that ELF field varies so slowly in time that Maxwell's equations are generally converted into the electrostatic and magnetostatic equations [21], and their effects to the human body can be studied and computed independently of one another [22]. Magnetostatic is magnetic field phenomenon produced by steady currents [23]. There are two laws governing the phenomena of magnetostatic field emission in space close to sources:

A. Biot-Savart's law

This law is also referred to as point source model. The current-carrying conductors are modelled as point source if length of conductors or conductor spacing is much smaller than observation distance [13]. The magnetic field of a steady current is expressed by Biot-Savart law as [23]:

$$\vec{B} = \frac{\mu_o}{4\pi}\int \frac{Id\vec{l}\times\hat{r}}{r^2} \qquad (1)$$

where $\mu_o = 4\pi \times 10^{-7} T \cdot m/A$ is the permeability of free space, I is the line current, $d\vec{l}$ is a differential element of the conductor in the direction of current, r is the distance between an observation point and a source point and $\hat{r}$ is a distance vector. The law specifies the direction and the magnetic field strength in the vicinity of conductor carrying-current [24].

B. Ampere's circuit law

This law is also referred to as long-conductor source model. The current-carrying conductors are modelled as long-conductor source if conductors are much larger than observation distance, as well as conductor spacing is much smaller than observation distance [13]. In power systems, magnetic field occur around the current-carrying conductor [25]. This symmetrical magnetic field generated by current distribution around the conductor can be determine by application of Ampere's law [26]:

$$B = \frac{\mu_o I}{2\pi r} \qquad (2)$$

where B is the magnetic field, I is the current flow through the long-conductor, μ_o is the permeability of free space and $2\pi r$ is the circumference of the magnetic field generated by current through a long-conductor.

2.0 Methodology

The instrument used for the measurement of extremely low frequency magnetic field was Extech 480826 triple-axis EMF metre manufactured by Extech Instrument. It was calibrated to flat frequency response, with frequency bandwidth of 30 to 300 Hz and sampling time of approximately 0.4 s. The three modes of selection with corresponding basic accuracy are 20 µT (4 %), 200 µT (5 %) and 2000 µT (10 %), and measured field isotropically with detachable external magnetic field probe.

The field probe for the Extech 480826 Triple-Axis EMF metre during the measurement of ELF magnetic field was mounted on special designed "field probe stand" constructed to correspond to three observation heights of 1.0, 1.5 and 1.8 meters of interest. The estimated standard for the occupational exposure was obtained by computing the mean from the three observation heights at each spot of measurement.

The field probe stand was mounted along with the sensor placed at the successive position in segmented manner in switchyard vicinity for detection and measurement of fields intensity. What informed the construction of the field probe stand was to have corresponding uniformity in height for measurement of the field levels throughout the survey, to guaranty degree of accuracy and stability of field reading. The mounted sensor was directly connected to the detector that displayed the values through 1m length sensor cable, which processed the signal from the probe. The resultant rms vector magnitude of unperturbed extremely low frequency magnetic field in three orthogonal directions was computed according to Institute of Electrical and Electronics Engineers [IEEE] 644-1994 standards for measurement procedure [27]:

$$B = \sqrt{B_x^2 + B_y^2 + B_z^2} \tag{3}$$

3.0 Results and Discussion

After exclusion of erroneous data that failed to meet the criteria for evaluation, a total of 767 data field were assessed and analysed for the five 330 kV switchyards of Hydro-plants and Gas-plants. The statistical analysis of the field data was performed using the IBM SPSS Statistics package (IBM version 21.0, USA). One-way analysis of variance (ANOVA) with significant level set at (*P* - value $\leq$ .05) was performed to compare the mean strength in ELF magnetic field generated between the switchyards with similar infrastructures, which operate at the same highest national voltage level of 330 kV. The essence of using ANOVA for analysis was to determine whether switchyard influences the level of ELF magnetic field generated within the vicinity. Table 1 presents summary of descriptive statistics, Test for Homogeneity of Variance, Robust test of Equality of Means and the Games-Howell Post Hoc test of Multiple Comparison of occupational exposure to ELF magnetic field level in the 330 kV switchyards of the electric generation stations in North-central, Nigeria.

NIPES-NCEE Conference Proceedings
The 2nd International Conference 15th-17th Feb. 2023
351-360
www.nipesjournals.org.ng

Table 1: Statistical Descriptive Data and Games-Howell Post Hoc Test in 330 kV Switchyards for ELF Magnetic Field Measurements

Variance	Descriptive Statistics			Test of Homogeneity of		Robust Tests of Equality of Means	
330 kV Switchyard	**N**	**Mean μT**	**Std. Deviation**	**Levene Statistics**	**Sig.**	**Welch**	**Sig.**
Shiroro Hydro-plant	183	5.0555	4.76172	16.842	.000	31.885	.000
Jebba Hydro-plant	164	5.7843	3.28311				
Kainji Hydro-plant	170	6.1780	3.18878				
Geregu Phase I Gas-plant	124	3.9473	3.21017				
Geregu Phase II Gas-plant	126	2.9426	2.42697				

330 kV Switchyards of Generation Stations		Mean Difference	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Shiroro Hydro-plant	Geregu Phase II Gas-plant	2.11285	.000	.9788	3.2469
Jebba Hydro-plant	Geregu Phase I Gas-plant	1.83699	.000	.7775	2.8965
	Geregu Phase II Gas-plant	2.84171	.000	1.9211	3.7624
Kainji Hydro-plant	Geregu Phase I Gas-plant	2.23066	.000	1.1923	3.2690

	Geregu Phase II Gas-plant	3.23538	.000	2.3394	4.1314
Geregu Phase I Gas-plant	Geregu Phase II Gas-plant	1.00472	.045	.0139	1.9956

* The mean difference is significant at the 0.05 level

The One-way between-switchyards ANOVA was performed with occupational ELF magnetic field as the dependent variable and generation switchyards as the independent variable. The results revealed significant differences between switchyards with Levene's statistic of $F(4,762) = 16.842$, $p < .001$ and, Kainji Hydro-plant switchyard ($N = 170$, $M = 6.18$, $SD = 3.19$) was observed to have the highest mean occupational exposure to ELF magnetic fields, while Geregu Phase II Gas-plant switchyard ($N = 125$, $M = 2.94$, $SD = 2.43$) was observed to have the least occupational exposure to extremely low frequency magnetic field.

Since the Levene's statistical test was significantly different at ($p < .001$), therefore, assumption for homogeneity of variance have been violated. So, the Null Hypothesis "there was no significant difference in occupational ELF magnetic field exposure level in 330 kV switchyards of both hydro-plants and gas-plants" stand rejected. The Welch robust test of equality of mean was then employed for the analysis because it is robust to violation of homogeneity of variances.

The Welch robust test of equality of mean demonstrated that the switchyards occupational exposure to ELF magnetic field level had statistically significant differences of ($p < .001$) between them.

To determine the specific groups that differed in exposure levels, Multiple comparison of Game-Howell Post Hoc tests was performed by assuming nonequality of variances for the five switchyards to identify which switchyard are significantly different from the other. As revealed in Table 1, the mean and 95% confidence intervals for emission level demonstrated Jebba Hydro-plant and Kainji Hydro-plant switchyards to have statistically significant differences of ($p < .001$) when independently compared to both Geregu Phase (I & II) Gas-plant switchyards, while Shiroro revealed significant difference of ($p < .001$) with Geregu Phase II Gas-plant and, significant difference of ($p = .045$) was observed between switchyards of Geregu Phase I and Geregu Phase II Gas-plant. However, nonsignificant differences were observed between switchyards of Shiroro, Jebba and Kainji Hydro-plants when compared with each other and between switchyards of Shiroro Hydro-plant and Geregu Phase I Gas-plant.

The means occupational exposure to extremely low frequency magnetic field in 330 kV switchyards of Kainji Hydro-plant (6.18 μT), Jebba Hydro-plant (5.78 μT) and Shiroro Hydro-plant (5.06 μT) were found to be significantly high when compared to 330 kV switchyards of Geregu Phase I (3.95 μT) and Geregu Phase II (2.94 μT). However, these exposure levels are still far below the expected set limit of 1 mT for occupational exposure proposed by ICNIRP. These results have revealed that the personnel working in switchyards at voltage level of 330 kV are not exposed to the same level of ELF magnetic field.

Medical research has shown that exposure to ELF magnetic field above safe limits can have a significant detrimental effect on health. The short-term exposure might cause nervous system disorder, abnormal cell activity, muscle pain and other effects while the long-term exposure might cause risk of neurodegenerative diseases [28]. Further studies revealed that it causes physiological change in human tissues [29], like neurological, cardiovascular disorders and low sperm count in the workers [30], because the nervous system has bioelectric properties that make it more vulnerable to be influenced by electromagnetic fields [31]. The possible effects on health are reinforced by the submission of WHO and IARC that time weighted average exposure to ELF magnetic field levels greater than 0.3 μT increases the likelihood of leukaemia [32].

5.0 Conclusion

The One-way ANOVA performed for the five 330 kV switchyards of Hydro-plants and Gas-plants to determine the density of ELF magnetic fields in the studied locations revealed that there exist significant difference in occupational exposure levels between switchyards. Even though the level of ELF magnetic field emission in the five switchyards have been found to be lower than the recommended permissible set limits of 1 mT by ICNIRP guidelines, there still exist variance in occupational exposure levels encountered by workforce. With government efforts for stability in power supply, the ELF magnetic field in the switchyards are expected to rise in future with increased load demand. Therefore, it is suggested that constant monitoring of fields level should be undertaken to detect high risk zone for possible avoidance to prolonged exposure for safe working environment.

References

[1] D. Urban, L. Tjong and K. Karipidis, "Measurement of extremely low frequency electric and magnetic fields associated with electricity supply and distribution infrastructure," Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), 619 Lower Plenty Road, Yallambie, Melbourne, 2014.

[2] I. J. Al-Faqeeh, M. Abu-Jafar and I. R. Abdelraziq, "The effect of the electromagnetic radiation from high voltage transformers on students health in Hebron district.," *International Journal of Geology, Agriculture and Environmental Sciences,* vol. 3, no. 1, p. 75–81, 2015.

[3] P. Nassiri, M. R. Monazzam, M. Yunesian, M. H. Sowlat, M. H. Safari, S. Momen Bellah Fard and S. A. Hosseini, "Extremely low frequency magnetic flux densities measured near hospital in Tehran," *International Journal of Environmental Research,* vol. 5, no. 4, p. 1035–1040, 2011.

[4] H. Jalilian, K. Najafi, M. R. Monazzam, Y. Khosravi and Z. Zamanian, "Assessment of static and extremely low-frequency magnetic fields in the electric-powered trains," *International Journal of Occupational Hygiene,* vol. 9, no. 2, p. 105–112, 2017.

[5] P. Rathebe, C. Weyers and F. Raphela, "Exposure levels of ELF magnetic fields in the residential areas of Mangaung metropolitan municipality," *Environ Monit Assess,* vol. 190, no. 544 , p. 1–9, 2018.

[6] Sudarti, L. Nuraini, T. A. Saleh and T. Prihandono, "The analysis of extremely low frequency (ELF) electric and magnetic field exposure biological effects around medical equipments," *International Journal of Advanced Engineering Research and Science (IJAERS),* vol. 5, no. 7, p. 289–296, 2018.

[7] R. Stam, "The Revised Electromagnetic Fields Directive and Worker Exposure in Environments with High Magnetic Flux Densities," Annal of Occupational Hygiene 2014, vol. 58, no. 5, p. 529–541, 2014.

[8] J. Vila, J. D. Bowman, L. K. L. Richardson, D. L. Conover, D. McLean, S. Mann, P. Vecchia, M. Tongeren and E. Cardis, "A source-based measurement database for occupational exposure assessment of electromagnetic fields in the interocc study: A literature review approach," Annals of Occupational Hygiene, vol. 60, no. 2, p. 184–204, 2016.

[9] S. Özen, "Evaluation and measurement of magnetic field exposure at a typical high-voltage substation and its power lines," *Radiation Protection Dosimetry,* vol. 128, no. 2, p. 198–205, 2008.

[10] G. Kulkarni and W. Z. Gandhare, "Proximity effect of high voltage transmission lines on humans," *ACEEE Int. J. on Electrical and Power Engineering,* vol. 3, no. 1, p. 28–32, 2012.

[11] M. Kokoruš, S. Delić, A. Mujezinović, M. Muratović and A. Čaršimamović, "Analysis of the possible solutions for the reduction of electric and magnetic fields near 400 kV overhead transmission lines," *Environmental Impact II,* vol. 181, p. 225–236, 2014.

[12] R. W. Habash, "Electromagnetic fields and radiation: Human bioeffects and safety," CRC Press, Ottawa, Ontario, Canada, 2001.

[13] I. O. Habiballah, M. M. Dawoud, K. Al-Balawi and A. S. Farag, "Magnetic field measurement & simulation of A 230 kV substation.," in *Proceedings of the International Conference on Non-Ionising Radiation at UNITEN (ICNIR 2003) Electromagnetic Fields and Our Health*, Kuala Lumpur, Malaysia, 2003.

[14] S. Helhel and S. Özen, "Evaluation of residential exposure to magnetic field produced by power lines near homes and working environments," *International Journal of Engineering and Applied Sciences (IJEAS),* vol. 2, no. 3, p. 1–10, 2010.

[15] L. Battistelli, A. Geri and G. Veca, "Magnetic field shielding of underground power cables in urban areas: A real-life example," *Boundary Elements,* vol. XXVII, no. 39, p. 527–540, 2005.

[16] Y. R. Ahuja, S. Sharma and B. Bahadur, "Autism: An epigenomic side-effect of excessive exposure to electromagnetic fields," *International Journal of Medicine and Medical Sciences,* vol. 5, no. 4, p. 171–177, 2013.

[17] C. Roldán-Blay and C. Roldán-Porta, "Quick calculation of magnetic flux density in electrical facilities," *Applied Sciences,* vol. 10, no. 891, 2020.

[18] International Agency for Research on Cancer [IARC], "IARC monographs on the evaluation of carcinogenic risks to humans: Non-ionising radiation, part 1, static and extremely low frequency (ELF) electric and magnetic fields," IARCPRESS, Lyon, France, 2002.

[19] H. Liu, G. Chen, Y. Pan, Z. Chen, W. Jin, C. Sun, C. Chen, X. Dong, K. Chen, Z. Xu, S. Zhang and Y. Yu, "Occupational electromagnetic field exposures associated with sleep quality: A cross-sectional study," *PLOS ONE,* vol. 9, no. 10, p. e110825, 2014.

[20] O. Johansson, A. Fragopoulou, Y. Grigoriev, L. Margaritas, L. Morgan, E. Richter and C. Sage, "The Seletun Scientific Statement," The International Electromagnetic Fields Alliance [IEMFA], Oslo, Norway, 2011.

[21] W. Tourab and A. Babouri, "Measurement and modelling of personal exposure to the electric and magnetic fields in the vicinity of high voltage power lines," *Safety and Health at Work (SH@W),* vol. 7, no. 2016, p. 102–110, 2015.

[22] A. Laissaoui, B. Nekhoul, K. Kerroum, K. K. Drissi and D. Poljak, "On the rotationally-cylindrical model of the human body exposed to ELF electric field," *Progress in Electromagnetics Research M,* vol. 29, p. 165–179, 2013.

[23] D. J. Griffiths, Introduction to Electrodynamics, 3rd ed., R. Alison and D. Kim, Eds., New Jersey: Prentice Hall, Upper Saddle River, New Jersey 07458, 1999.

[24] I. N. Ztoupis, I. F. Gonos and I. A. Stathopulos, "Calculation of power frequency fields from high voltage overhead lines in residential areas," in *Paper presented at the 18th International Symposium on High Voltage Engineering*, Seoul, Korea, 2013.

[25] C. Kocatepe, C. F. Kumru and E. Taslak, "Analysis of magnetic field effects of underground power cables on human health," in Paper presented at the 5th International Symposium on Sustainable Development (ISSD 2014), Sarajevo, Bosnia and Herzegovina, 2014.

[26] N. O. M. Sadiku, Elements of Electromagnetics, 3rd ed., Philadelphia, US: Saunders, 1989.

[27] Institute of Electrical and Electronics Engineers [IEEE] Standards Coordinating Committee 39 , "IEEE recommended practice for measurements and computations of electric, magnetic and electromagnetic fields with respect to human exposure to such fields 0 Hz to 100 kHz," IEEE 3 Park Avenue, New York, NY 10016–5997, USA, 2010.

[28] N. Raghu, M. N. Krishna, K. Nagendra and V. N. Trupti, "Survey of electromagnetic field near EVH lines and their health hazards," in Paper presented at the International Conference on Smart Grids, Power and Advanced Control Engineering (ICSPACE2017), Bangalor, India, 2017.

[29] S. Bhattacharjee, "Protective Measures to Minimize the Electromagnetic Radiation," Advance in Electronic and Electric Engineering, vol. 4, no. 4, pp. 375-380, 2014.

[30] O. Aliyu, I. Maina and H. Ali, "Analysis of electromagnetic pollution due to high voltage transmission lines," Journal of Energy Technologies and Policy, vol. 2, no. 7, p. 1–10, 2012.

[31] J. Huang, T. Tang, G. Hu, J. Zheng, Y. Wang, Q. Wang, J. Su, Y. Zou and X. Peng, "(2013) Association between exposure to electromagnetic fields from high voltage transmission lines and neurobehavioral function in children," PLoS ONE, vol. 8, no. 7, p. 1–10, 2013.

[32] World Health Organisation [WHO], "Exposure to Extremely Low Frequency Fields," WHO|Electromagnetic fields and public health, 2007.