ELECTROMAGNETIC FIELDS CHARACTERISTICS FROM OVERHEAD LINES, UNDERGROUND CABLES AND TRANSFORMERS DETERMINED USING FINITE ELEMENT METHOD

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DEDICATION

To my beloved family and relatives

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ABSTRACT

Electromagnetic fields (EMF) are combinations of invisible electric and magnetic fields of force collectively where electric fields are proportional to electric charges, and magnetic fields are proportional to electric currents. Those fields may have detrimental potential health effects and can be in our homes or workplaces. There are many uncertainties about those emissions. This research is to clarify and answer those questions. This study focuses on magnetics fields only as it can vary. therefore, this project is to simulate and analyse magnetic fields radiations in the vicinity of 132 kV overhead power lines for two cases; with straight conductors and with conductors sags, 11 kV triangular straight underground cable for two cases; as $185\,mm^2,$ and $120\,mm^2$ cross sectional area at 0.9 m in depth, and for 1000, 1600, and 2000 kVA transformers determined using finite element method via ANSYS Maxwell. Also, to compare the results with the safety limits as defined in recent international standards. The results for 132 kV double circuit overhead power transmission straight lines show a highest magnetic field magnitude of 38 μT while with conductors sags a highest magnetic field of 51.2738 μT. For underground cables, the results show $185\,mm^2$ bigger cross-section area cable has higher magnetic fields compared to the smaller cross section cable with the highest magnetic fields of 97.6598 μT and 44.89 μT respectively. For transformers, the highest magnetic field was obtained by applying peak load current to the upper and lower windings in each phase for each geometry models and examined both far and near fields in two directions. The highest magnetic field obtained for far fields of 2000 kVA transformer is 110.50 μT. Those fields data are collected at one meter high. The allowable limits are set in ranges (200-1000 μT) and (0.9-3mT) for ICNIRP 2010 and IEEE 2019 respectively based on 50 Hz. The results are showing safe exposure level of magnetic fields as long as the distance is respected. It is advisable that safety precautions should be taken to prevent prolong exposure of EMF radiation to human body.

ABSTRAK

Medan elektromagnetik (EMF) adalah gabungan medan daya elektrik dan magnet yang tidak dapat dilihat secara kolektif di mana medan elektrik berkadaran dengan cas elektrik, dan medan magnet berkadar dengan arus elektrik. Bidang tersebut mungkin mempunyai kesan kesihatan yang berpotensi memudaratkan dan boleh berada di rumah atau tempat kerja kita. Terdapat banyak ketidakpastian mengenai pelepasan tersebut. Penyelidikan ini adalah untuk menjelaskan dan menjawab persoalan tersebut. Kajian ini hanya memfokuskan pada medan magnet kerana boleh berbeza. oleh itu, projek ini adalah untuk mensimulasikan dan menganalisis radiasi medan magnet di sekitar saluran kuasa overhead 132 kV untuk dua kes; dengan konduktor lurus dan dengan kendur konduktor, kabel bawah tanah lurus segitiga 11 kV untuk dua kes; sebagai luas keratan rentas $185\,mm^2$, dan $120\,mm^2$ pada kedalaman 0,9 m, dan untuk transformer 1000, 1600, dan 2000 kVA ditentukan menggunakan kaedah elemen hingga melalui ANSYS Maxwell. Juga, untuk membandingkan hasilnya dengan had keselamatan seperti yang ditentukan dalam piawaian antarabangsa baru-baru ini. Hasil untuk garis lurus transmisi kuasa overhead litar berkembar 132 kV menunjukkan magnitud medan magnet tertinggi 38 µT sementara dengan konduktor merosakkan medan magnet tertinggi 51.2738 µT. Untuk kabel bawah tanah, hasilnya menunjukkan kabel luas keratan rentas $185\,mm^2$ yang lebih besar mempunyai medan magnet yang lebih tinggi berbanding kabel keratan rentas yang lebih kecil dengan medan magnet tertinggi masing-masing 97.6598 µT dan 44.89 µT. Untuk transformer, medan magnet tertinggi diperoleh dengan menerapkan arus beban puncak ke belitan atas dan bawah dalam setiap fasa untuk setiap model geometri dan memeriksa medan jauh dan dekat dalam dua arah. Medan magnet tertinggi yang diperoleh untuk medan jauh pengubah 2000 kVA ialah 110.50 µT. Data ladang dikumpulkan pada ketinggian satu meter. Had yang dibenarkan ditetapkan dalam julat (200-1000 µT) dan (0,9-3mT) untuk ICNIRP 2010 dan IEEE 2019 masing-masing berdasarkan 50 Hz. Hasilnya menunjukkan tahap pendedahan medan magnet yang selamat selagi jaraknya dihormati. Sebaiknya langkah keselamatan diambil untuk mengelakkan pendedahan radiasi EMF yang berpanjangan ke tubuh manusia.

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LIST OF ABBREVIATIONS

WHO	-	World Health Organization
IEEE	-	Institute of Electrical and Electronic Engineer
ICNIRP	-	International Commission on Non-Ionization Radiation Protection
NRPA	-	International Radiation Protection
IRPA	-	International Radiation Protection Agency
IARC	-	International Agency of Research on Cancer
EMF	-	Electromagnetic field
ELF	-	Extremely low frequency
ROW	-	Right of Row
ACSR	-	Aluminium Conductor Steel Reinforced

LIST OF SYMBOLS

kV	-	Kilovolt
Hz	-	Hertz
mT	-	Militesla
E	-	Electric field
B	-	Magnetic Field
H	-	Magnetic field strength
D	-	Electric displacement
J	-	Current density
ρ	-	Charge density
c	-	Speed of light
μ_0	-	Permeability of free space $= 4\pi \times 10^{-7} T.m/A$

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CHAPTER 1

INTRODUCTION

1.1 Background of study

Electricity has become critical in our daily life especially in modern and industrial cities as it does make our life easier. Consequently, electricity demand keeps on rising, towns keep on expanding and become closer to power systems especially in crowded population regions. Many electrical systems involving either apparatus or conductors are available around us, forming network to meet the increasing electricity demand and to transmit energy from generation stations to the load centers. Furthermore, the use of machinaries and high voltage applications also keep on increasing which leads to the concern of EMF radiation from these sources. As a result, people are getting exposed to electromagnetic radiation without them being realise since it is invisible and silent to our eyes or ears. Furthermore, the effects cannot be felt and seen directly. People can receive electromagnetic radiation continuously from different kinds of sources such as generation stations, power lines, substations, industries, electrical panels, wires, home appliances, and other countless load centers. In the last decades, many countries had shown their concern about electromagnetic field (EMF) radiation which is taught to be associated with many health hazards especially cancer. Large number of researches were done and the results were analysed and presented from different perspectives such as in medical, biological, physical, chemistry, and engineering fields [1].

Electromagnetic fields which consists of electric and magnetic fields have become a great concern since the past decades and recently, the measurements, calculations, simulations, and evaluation of these fields radiations are becoming more common. Electric fields are proportional to electric charge intensity while magnetic fields are proportional to the current intensity flowing through the lines, cables, and electrical devices. Intensity of these radiation is affected with increasing distance from the radiation source. Electric fields are measured in Volts/meter (V/m) or sometimes in kilovolts per meter (kV/m) while magnetic fields is measured in micro (μT) or milli Tesla (mT). Magnetic fields radiation can be found in different countless technologies but in electrical power systems it is considered as extremely low frequency (ELF) because their frequency normally does not exceed 300 Hz, man-made, non-ionize, and has no thermal effect.

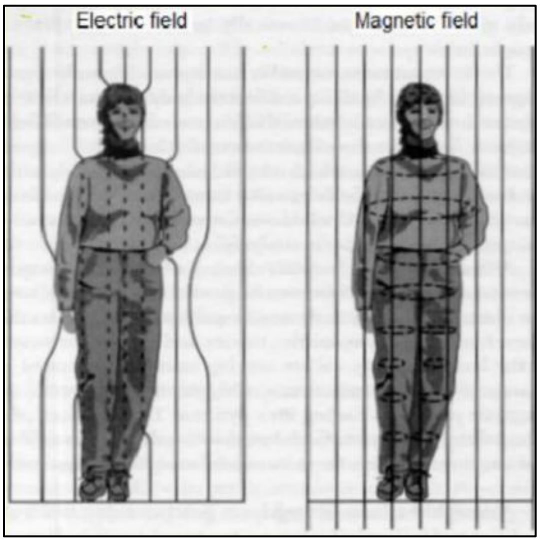

Figure 1.1 Low frequency electric and magnetic fields [2]

Humans and environment receiving magnetic energy from power sources. The dotted lines as shown in Figure 1.1 allow us to see the directions of the induced currents parallel to the electric field and perpendicular to the magnetic field. It is very simple to disturb the electric field with objects and materials such as buildings, trees, or human skin while the magnetic field does not get affected easily by materials because they have a high potential to go through everything except if it has a high concentration of iron [2].

1.2 Problem statement

The presence of electric currents has strong links with EMF emissions and if it is not managed properly, this emission may risk the health of living organisms whom are near to those sources. Electric fields can be screened by objects such as buildings, trees, and wall while magnetic fields cannot be shield completely. Therefore, prolong exposure to magnetic field radiation from overhead lines, underground cables, transformers, and other electrical appliances may be harmful to human body. According to statements released by World Health Organization (WHO) and International Commission on Non-Ionizing Radiation Protection (ICNIRP), everyday exposure to chronic low-intensity currents can rise different kinds of health effects, classified into short and long effects. In the short term, it causes headaches, fatigue, anxiety, insomnia rashes, and muscle pain while in the long term it causes leukemia, brain cancer, breast cancer, and skin cancer[3]. According to the recent standard released by the Institute of Electrical and Electronics Engineers (IEEE) in 2019, people whom exposed daily to chronic low intensity (above 0.9–3 mT) magnetic fields may increase health risks, potentially leading to leukemia, especially in children[1]. Besides that, the International Agency for Research on Cancer (IARC) has classified such fields as possibly carcinogenic to humans (Group 2B) but there is no clear evidence to justify the relationship between the electromagnetic fields and severe diseases such as cancers [3]. Furthermore, individuals are concerned or nervous about their healthy life, and the working environment, and their crop since they have read or heard stories about this problem.

1.3 Objectives

The main objectives of this research are:

(a) To simulate and analyse magnetic fields radiation in the vicinity of overhead power lines, underground cables, and transformers using finite element method via ANSYS Maxwell.

(b) To compare the results with the limits of the guidelines as defined in the international standards.

1.4 Project Scopes

This research work is focusing on analysing the magnetic field radiation from 132 kV double circuit overhead power transmission lines, 11 kV underground cables with different sectional cross area, and transformers. The analysis is done through simulation work using finite element method via ANSYS Maxwell. No measurement was conducted for this research work because of limitation and restriction due to Covid19 pandemic. The simulation results were compared with the recent guidelines for safe limit exposure recommended by the World Health Organization (WHO).

1.5 Significance of the study

The advantage of this research is to see how those magnetic fields radiation behaves in power systems as in transformers or conductors which can be located anywhere around us and to evaluate the magnitude of radiations and validate how they are varying to the receivers especially regarding the probability of health hazards associated with those different sources.

1.6 Thesis Organization

The project report is outlined in the following manner

Chapter 2, consists of general concepts reviewed from previous related work. Introduction, discussion of the theoretical framework, safety limits based on recent international standards, and potential of health hazards were explained and elaborated in detail in this chapter.

Chapter 3, discusses the methodology adopted on how this research works was conducted. The research design, flowchart, and how does the simulation works was carried out using ANSYS Maxwell were discussed appropriately.

Chapter 4, states the findings in quantitative analysis and interprets the meaning of the results, and compare them to the recent international guidelines.

Chapter 5, concludes the findings of this study where the magnetic field and electric field values within the allowable range and safety precautions should be considered.

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