ANALYSIS AND MEASUREMENT OF MAGNETIC FIELD EMISSION NEAR HIGH VOLTAGE TRANSMISSION LINES (HVTL)

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ABSTRACT

Magnetic field is produced whenever current flow based on the Ampere's Law. The study of magnetic field distribution in the vicinity of high voltage transmission lines is very important due to its potential health effects. This is because of the low frequency magnetic field from high voltage transmission lines which today are very close to building in the cities, due to the rapid development. According to WHO no real prove that magnetic radiation from power transmission line is hazardous to the people however, still the researchers and the population are concerned about it. This project is to analyze and measure the magnetic field emission from various configurations of 132Kv high voltage transmission line.The measurement was done by using EMDEX II Electric and Magnetic Field Digital Exposure System,which is a hardware and software package designed to measure, record, and analyze power frequency magnetic fields. The result shows that it is very below the limit sets by ICNIRP.

We had developed some equations and Maltlab Graphic User Interface for double circuit 132Kv vertical configuration based on Bio-Savart's law and Maxwell's equations, to make easy for the researchers to calculate the magnetic field, it was use the superposition method of multiple conductors. to collect data both for time and distance varying in Batu Pahat, Malaysia. Furthermore, the emission was high within 10:45 am to 11:15 am and from 1pm to 3:30pm, the highest recorded value was 12mG. Based on our results there are a few number of parameters that determine the magnetic field, namely the current magnitude, the high of the conductor above the ground and the space between the conductors. The correct phase arrangement can reduced the magnetic up to 91.5% and the increment of 8m in the height will reduce 79% of magnetic emission.

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List of Symbols

D/C Double Circuit

DC Direct Current

ECR European Council Recommendation

EDM Electronic Distance Meter

EMC Electromagnetic Compability

EMDEX II Electric and Magnetic Field Digital Exposure

G Gauss

HVTL High Voltage Transmission Lines

ICNIRP International Commission on Non-Ionizing Radiation Protection

IEEE Institute of Electrical and Electronics Engineers

IRPA International Radiation protection Agency

LINDA Linear Data Acquisition

MATLAB Matrix Laboratory

mG Milli-Gauss

NRPB National Radiological Protection Board

OHTLs Overhead High Voltage Transmission Lines

PTL Power Transmission Line

ROW Right Of Way

uT	Micro-Tesla
WHO	World Health Organization

Chapter 1

INTRODUCTION

1.1 Background of Study

Nowadays, the modern society is highly dependent on electricity, it is nearly impossible to survive in the future without this precious energy. During the last two decades , industrialized countries are more concerned with an increase in EMF which has health hazards. The potential hazard to human health for living things near the overhead high voltage transmission lines. Electromagnetic field radiated from HVTLs and electrical equipments may create low and weak electric current through our bodies (Qabazard, 2007).

In crowded regions, as a result of towns´s expansion during the last decades, HVTLs which were far from people, are now close to the residential houses. Mostly the previous investigations had shown no really serious effects on human health from the EMF due to HVTL , but recent studies have taken the opposite side. Besides HVTLs, there are a good number of appliances that possibly radiate EMFs such as electric blankets, copy machines, monitors and televisions which need to be studied according to Ahmadi *et al.* (2010). This work has investigated measured, and analyzed the EMF in the proximity of HVTL in Batu Pahat, Johor, Malaysia which has been selected as a physical example for studying purposes. Nonetheless, there is no general agreement about the acceptable limited value of environmental electromagnetic fields, or induction currents produced by these fields in human body.

Since late 1970s, when Wertheimer and Leeper suggested the existence of a connection between the presence of overhead high transmission lines and certain illnesses (leukemia and other types of cancer), there has been a great deal of discussion regarding the possible effects of electromagnetic fields on living beings (Munoz *et al.*, 2013).

The exact calculation of these electromagnetic fields requires the use of Maxwell's equations. Only very simple geometries in magnetic field by direct integration of Maxwell's equations can be calculated as it is was first formulated. Subsequently, different methods of analysis and calculation have been developed on the basis of highly complex mathematical formulations in respect to both time and the frequency dimension. It was entail two main advantages in respect to other techniques, namely it has provided information regarding the parameters that affect the magnetic field generated by overhead lines and allow analyzing new configurations in a simpler manner.The method used in Munoz *et al.* (2013) using double complex number, allowing the simultaneous treatment of position vectors and phasors in order to obtain exact expressions.The result obtained from 132KV double circuit vertical configuration in Munoz *et al.* (2013) is showed on Figure 2.1.

Many authors have used numerical methods, such as the Finite Element Method [DhanaLakshmi *et al.*, 2011,Hameyer *et al.*, 1995] the Charge Simulation Method (Elhirbawy *et al.*, 2002) and the Finite Difference Method (Elhirbawy *et al.*, 2002). The large amount of computational resources required by numerical methods to be feasible for the calculation of magnetic fields produced by overhead lines in a reasonable time. Furthermore, there are some disadvantages related with the meshing process, execution time, and others. The disadvantage is that they require a numerical integration of higher order. The above consideration justify the need for new efficient procedures able to obtain the magnetic field at any point in space easily and user friendly . This project has adopted Maxwell's equations by superposition method from only basic parameters such as phase currents and the position of the conductors with respect to the calculation point . The result was compare with the measured values by EMDEX II.

1.2 Problem Statement

Our concern here is the electromagnetic emission, which is associated to heath effect. Both electric and magnetic are produced whenever electricity is used, in other words, when there is flow of current in a conductor. Previously the HVLs are far from the residential areas, however, today due to the development of the countries and the dramatic grow of the populations. According to Shahrom (2012) not many people live near the HVLs (within 100m), but those whom do so, this will be a great source of exposure.Current in ampere can be likened to the volume of water circulating in pipe hose when the nozzle is open. Usually, the greater the amount of the current is higher the magnetic field due to their direct proportionality. The MF is generally measure in micro-Tesla (uT) or milli-gauss (mG).

This magnetic radiation is a real problem to those who are leaving near the HVLs; hence our concern is to let aware the population of the danger. A review published by the WHO in June 2007 (Standard, 2008) recommended using exposure guidelines published by the ICNIRP. Magnetic fields are basically energy reservoirs with an energy density of $e = B^2/2\mu_0$,$Joules/m^3$, where B is in Tesla and $\mu_0 = 4\pi x 10^{-7}$Henry/meter. This energy is known to affect tissues in human body in everyday activities(Begamudre, 2006). Some of the effects are known to be beneficial such as being used medically for healing broken bones, but most of them are harmful and pose health hazards among which have been counted cancer of many types. These cancers are: leukemia or blood cancer, lymphoma which weakens the immune system of the body to cancerous conditions, nervous disorders leading to brain damage such as Alzheimer disease, breast cancer in both female and male species, and several other dangerous conditions too numerous to enumerate here. The magnetic radiation at low frequency emanating from Video Display Terminals such as are used by secretaries in banks, offices and so on is suspected to cause not only skin rash, eye problems, tissue cancer but more importantly are known to give rise to spontaneous abortions in pregnant women operators thereby forcing an end to pregnancy (Begamudre, 2006).

The study of health hazards associated with power-frequency (50 Hz) magnetic fields has gained world-wide importance in medical, biological, physics and engineering fields and it is the subject of intensive study, including the magnetic-field radiation near HVT lines and distribution lines. We had only describe and discuss a few basic facts and mechanisms that give rise to health hazards associated with magnetic fields (Begamudre, 2006).

1.3 Objectives

The objectives of this work are to :

1. Perform analytical calculation on the magnetic field distribution under 132KV High Voltage Transmission Lines

2. Measure the magnetic field and compare with analytical calculation.

3. Suggest practical ways to shield against 50Hz magnetic field.

1.4 Project Scope

This project is only about 50 Hz power frequency magnetic field radiation. Moreover, in Malaysia beside of the 50Hz frequency the high voltage transmission is categorize in 132 KV, 275 KV and 500KV however this work was concentrated on 132KV. This is chosen because it is the most common and used in the cities in Malaysia. The literature review has covered the basic theory related to electromagnetic field, some equations related to EMF and lastly it has given some brief information about the equipments used during our work. Last but not least, the result from the measurement and the analytical has been compared, furthermore, all the comparisons were made base on the limit of acceptance exposure that applied internationally (ICNIRP, IEEE etc.) .

Chapter 2

LITERATURE REVIEW

2.1 Introduction

This chapter will give brief introduction about electromagnetic, high Voltage Transmission Lines and some information about the equipments and software used in this project. Electric and magnetic fields are produced by any wiring or equipment carrying electric current. This includes overhead and underground power lines carrying electricity, wiring in buildings, and electrical appliances. Furthermore, some important papers on the present topic have been investigated and summarized.

The strengths of fields decrease rapidly with increasing distance from the source. Electric and magnetic fields are fundamentally different, in their physical nature and in the way they interact with the body, form true electromagnetic radiation such as radio waves and microwaves. This chapter will include the summary of some precedent works that have been done previously by other researchers on EMF (magnetic fields near the HVTL). Information collected and obtained from these various studies in the past will be the main reference aside from findings made during the research process. These will assist in the purpose of finding the simplest possible equation of calculating the magnetic field under and around overhead power line.

International Exposure Guidelines, International EMF public exposure guidelines are set at levels designed to protect people from known harmful effects of EMF. The ICNIRP guidelines(Standard, 1998) were published in 1998 and adopted by European Council Recommendation (ECR) in 1999.

Theories regarding the fundamental and ground rules of magnetic field are also being explained in this chapter. The evolution and development of the most basic to the most complex equation are studied and stated. From these equations, improvement can be made to alleviate and ease the calculation method.

The Figure 2.2 shows a typical electrical power system, from the generation (black), transmission (Blue) until the distribution (green) but our main concern in this work is path that is drawn in blue color on Figure 2.2

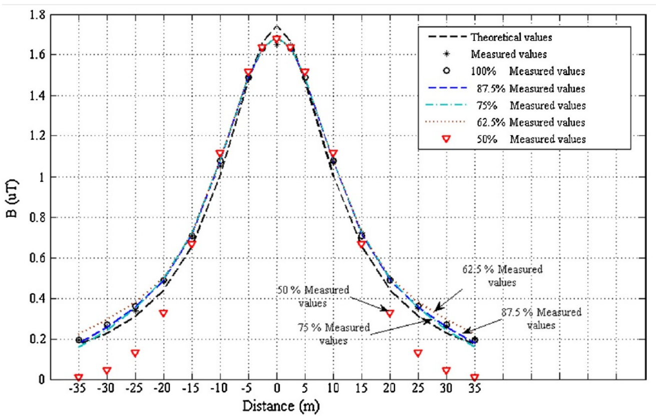


Figure 2.1: Magnetic field for 132KV double circuit vertical configuration in Munoz *et al.* (2013)

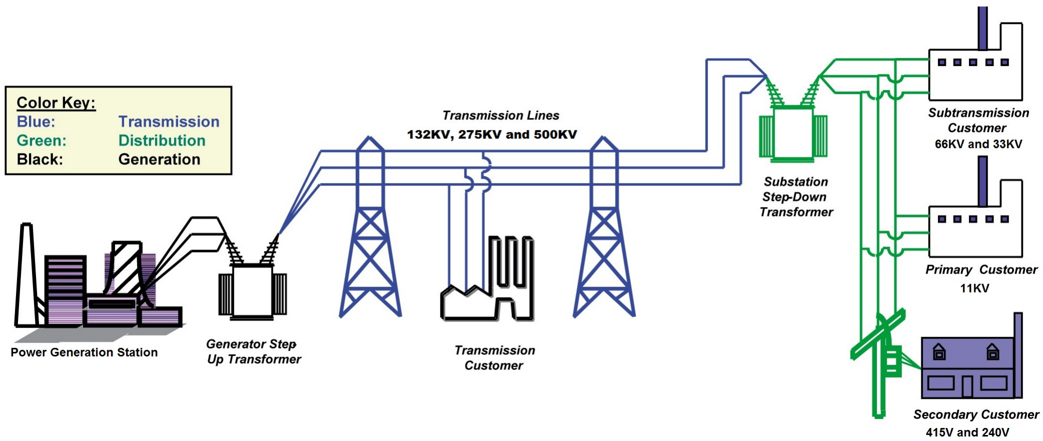


Figure 2.2: Power system representation

2.2 Measurement and Equipment

2.2.1 Equipment

2.2.1.1 EMDEX II - Magnetic Field Measurement System

The EMDEX II Electric and Magnetic Field Digital Exposure System is a hardware and software package designed to measure, record, and analyze power frequency electric and magnetic fields. The complete system consists of :

1. The EMDEX II exposure meter,

2. The LINDA System which uses the EMDEX II meter,

3. The Amp-Logger Model 200A, an interface device which allows the EMDEX II to be used as a recording clamp-on ammeter with a Fluke AC current probe,

4. The E-Probe, an electric field sensor which allows the EMDEX II to record electric field values, and

5. The EMCALC Software System.

The EMDEX II is a programmable data-acquisition meter which measures the three orthogonal vector components (X, Y, and Z axes) of the magnetic field through its internal sensors. Measurements are stored in the meter's memory and later transferred through a serial communications port to a personal computer (PC) for storage, display and analysis. During data collection, magnetic field values are displayed on the meter's LCD display. The size and weight of the EMDEX II make it suitable for both personal measurements or for use as a stationary area monitor; its flexibility and ease of use make it adaptable to simple and complex measurement protocols.

The EMDEX II meter uses an internal operating program to specify the data collection parameters. The external sensor measurements, the internal operating program should be design for use with an appropriate instrument. However, magnetic field measurements are always recorded by the EMDEX II meter, regardless of which other accessories or external sensors are used.The EMDEX II allows to start and stop up to 20 measurement sessions (called data sets) before you must download data to the PC. Data sets are independent from each other and can have completely different measurement options (ENERTECH, 2008).

Figure 2.3: EMDEX II Accessories

Figure 2.4: The EMDEX II Magnetic Field Meter (Date : 10/11/13)

2.2.1.2 LINDA wheel

The EMDEX II meter uses an internal operating program to specify the data collection parameters. A special program, the LINDA Internal Operating Program, must be running on the EMDEX II to use the LINDA System. The LINDA Internal Operating Program normally must be transferred from a personal computer to the EMDEX II each time the EMDEX II is turned on (however, the LINDA program can be permanently installed on the EMDEX II so it automatically runs without going through the installation procedure).

The LINDA system is an accessory for the EMDEX II magnetic field measurement system. LINDA uses a customized measurement wheel and an EMDEX II meter to measure magnetic field and distance along a path. A magnetic switch mounted on LINDA's wheel sends a signal to the REMOTE jack on the EMDEX II every 1 foot of travel. Because the EMDEX II records data at a fixed rate, the user may walk slowly with the LINDA wheel to produce detailed measurements over a short distance or may walk quickly to produce more generalized measurements over longer paths. Angular changes in direction are entered by the user into the EMDEX II using the up/down and event marker buttons. This allows a user to map the field over an area.

The LINDA Measurement System is composed of :

- An EMDEX II using the LINDA Internal Operating Program.

- A PC with the EMCALC software installed, allowing communication with the EMDEX II meter, transferring of data from the meter to the PC, and data storage and analysis.

- The LINDA Measurement Wheel, often referred to as simply "LINDA" (Figure 2.5) (ENERTECH, 2001).

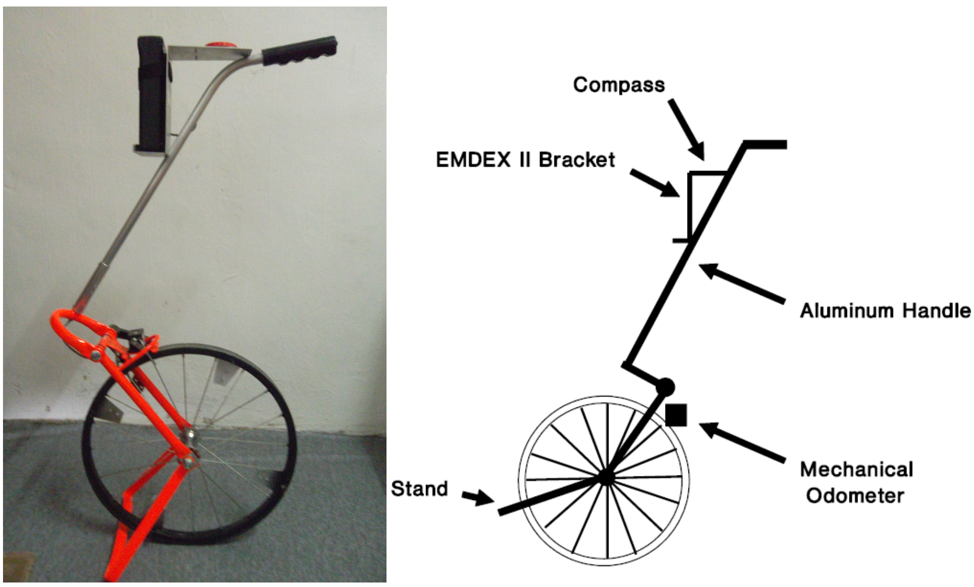


Figure 2.5: The LINDA Measurement Wheel (Date: 06/10/13)

2.2.1.3 Distance and Height Calculations

A total station is an electronic/optical instrument used in modern surveying and building construction. The total station is an electronic theodolite (transit) integrated with an electronic distance meter (EDM) to read slope distances from the instrument to a particular point.That is provide in UTHM, Faculty of Civil Engineering in Makmal Geomatik. Besides, we had used as well the Fluke distance meter provided by EMC center. The Fluke 411D is a professional-grade laser distance meter, it's fast, easy to use, and fits on your tool belt. This meter will save you effort and money by reducing measurement time and errors.These meters offer the most advanced laser technology for distance measurement.

(a) Total station

(b) Fluke distance meter

Figure 2.6: Distance & Height measurement device (Date : 23/11/13)

2.3 Previous Works

Several research studies related to the propagation of EMF around overhead power lines and the relationship between magnetic fields and the health of people are increasingly being investigated. In this section, some of the most related studies that have been conducted are being analyzed and summarized. Previous studies used to provide a guide in order to achieve the stated aim of this study.

2.3.1 Power Transmission line magnetic fields: survey on 120KV overhead power transmission lines in Malaysia

Azzuhri & Mahadi (2004) emphasized on the extremely low frequency (ELF) magnetic fields because this is the subject that is believed to have more effect to human health. The basic and properties as it provides the basic understanding of magnetic fields generated by the power transmission lines.

The main focus of this paper is magnetic fields that associated with 50Hz power transmission lines. In a situation where the voltage is 120KV, from tower overhead power transmission lines the specified line was selected because it has been the most common line usage in Malaysia and can easily be spotted alongside the road and highways.

The instrumentation includes EMDEX SNAP (Enertech Consultants, USA) is used to measure the magnetic flux densities using three orthogonally mounted sensors.Figure 2.7 shows an example of EMDEX SNAP. The EMDEX II is a programmable data-acquisition meter which measures the three orthogonal vector components (X, Y, and Z axes) of the magnetic field through its internal sensors. Measurements are stored in the meter's memory and later transferred through a serial communications port to a PC for storage, display and analysis during data collection, magnetic field values can also be displayed on the meter's LCD display. The size and weight of the EMDEX II make it suitable for both personal measurements or for use as a stationary area monitor, its flexibility and ease of use make it adaptable to simple and complex measurement protocols.

Figure 2.7: EMDEX used to measure Electromagnetic field. (Date : 10/11/13)

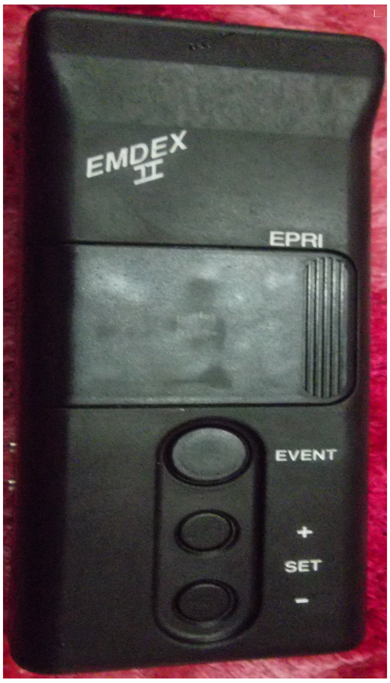


Figure 2.8: EMDEX used fot our measurement

2.3.2 Evaluation of magnetic field from different power transmission line configurations in Malaysia

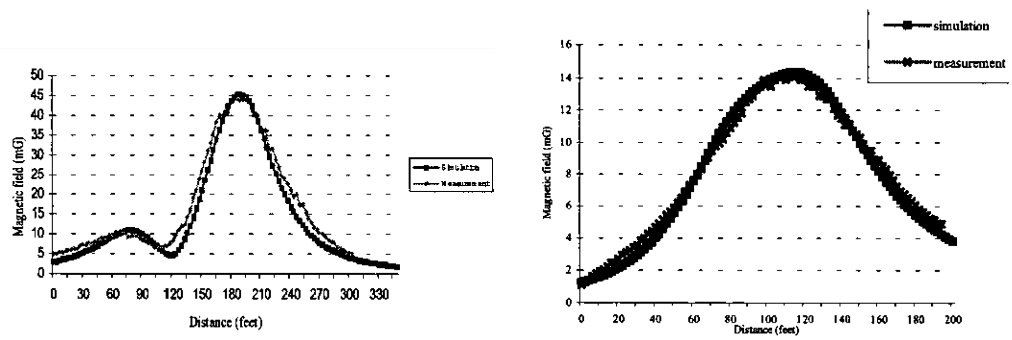
The paper written by Said *et al.* (2004) was conducted based on the concerns on magnetic field propagation at various transmissions lines configurations in Malaysia. This is due to rapid infrastructure; it has urged the utility company to enhance electrical transmission capacity in order to ensure adequate and reliable supply to the consumers. In certain places, under different circumstances it could consists of six towers energized within the same land evaluate reserve.

Based on that, the author of this paper find that there is a requirement to study and evaluate the impact of EMF exposure levels for these multiple towers. Accordingly, this paper presents the result of magnetic field measurement at various transmission line configurations.

The findings of this paper revealed that the magnetic field of overhead electric power transmission line is generally affected by a number of variables which are, the magnitude of phase current, height of the conductors above the ground, the configuration of the conductors and the lateral distance between towers.

The different configuration of the transmission lines taken into consideration are two double circuit towers. It was for measurement purposes, magnetic field measurement were done using three axis EMDEX II meters and the linear data acquisition system LINDA wheel from Enertech consultants, where it was measured 1 meter above the ground, different type of transmission line configurations, were constructed using the FIELDS program. The comparison was meant to verify the models constructed. Examples presented on the comparison are shown in Figure 2.9.

Figure 2.9(a) shows the magnetic field measured and simulated for two double circuit tower configurations while Figure 4.7(b) shows comparison for one quadruple circuit tower configuration.



(a) Magnetic field measured and simulated for two double circuit tower configuration

(b) Comparison for one quadruple circuit tower configuration

Figure 2.9: Data validation between measurement and modeling (Said *et al.*, 2004).

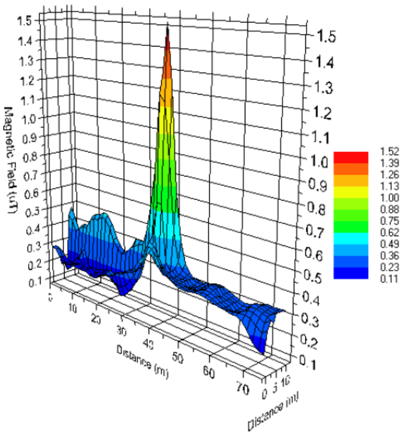
As a conclusion, it was shown that the quadruple tower configuration for the transmission line system provides lower maximum magnetic field and lower magnetic field at right of way (ROW) for the same load capability. The method adapted to for the research is the comparison made between the measured and simulated modeling data.

The conclusion made by study is, the highest of magnetic field recorded was located at the center-line and it had been assumed that power consume was at its peak. From this statement, the area, as suggested by the authority is 20 meters from the center-line, where activities should be carried out.The paper by Rahman *et al.* (2005) indicated that magnetic fields reduction up to 75% is achievable by correct phase arrangements technique carried out on the scaled down model transmission line.

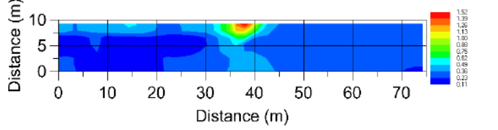
2.3.3 Measuring human exposure to magnetic fields near EHV 400 KV GIS substation and power lines in state of Qatar.

The paper written by Ellithy *et al.* (2011) is rather similar to the paper by Said *et al.* (2004). Apart from the different location that this study was being conducted and the different is transmission line focused, the purpose is the same which is to measure the levels of magnetic fields inside and around the fence of 400 KV gas insulated substation from the public exposure point of view. The measurement were conducted at 1 m above the ground in line with IEEE recommendation the measurements were taken using the same equipment, EMDEX II meter and LINDA system.

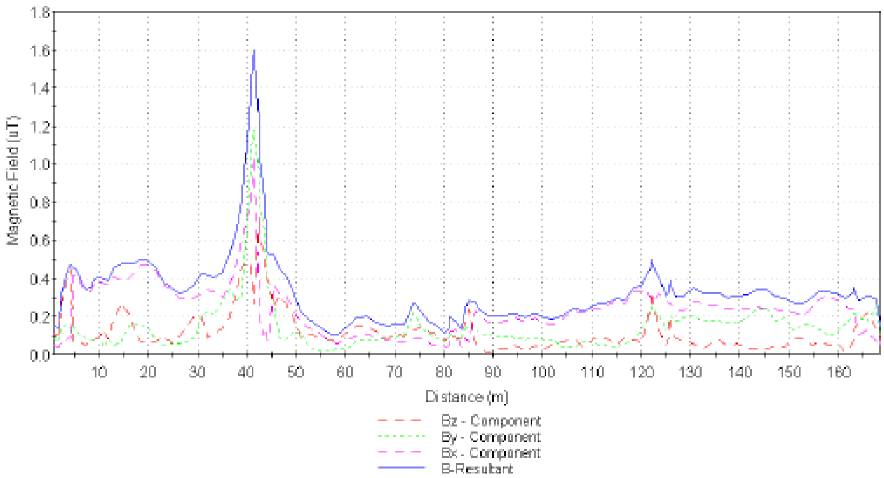
In addition to the paper by Said *et al.* (2004), the resulting magnetic fields distribution are presented in a variety of graphical format including 3-D plots and contours maps to facilitate the location of high intensity magnetic field zones inside the situation. The measured magnetic fields levels are compared with the levels recommended by international standards. The measured magnetic fields levels are compared with the levels recommended by international standards. The magnetic field of 400KV overhead power line is calculated and compared with the measurement taken. The resulting data is presented as shown in Figure 2.10.



(a) Measured magnetic field 3-D plot around the perimeter of the 400kv substation control room

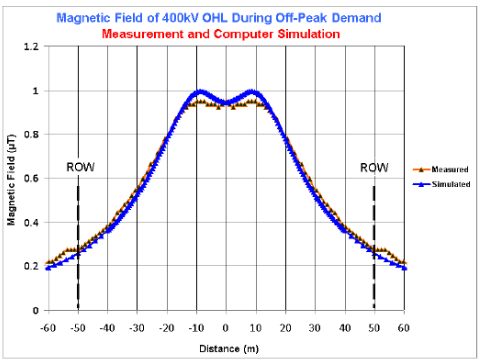


(b) Measured magnetic field contours maps around the of 400kv substation room

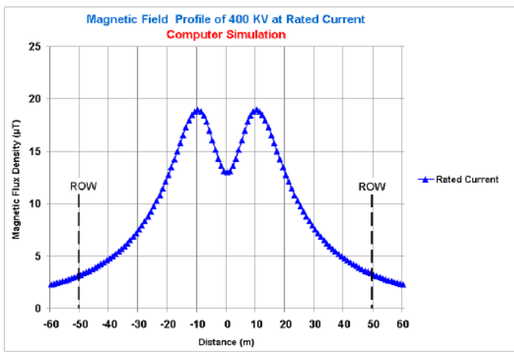


(c) Magnetic field around the 400KV

Figure 2.10: : Magnetic field around the perimeter of 400Kv overhead power line..(Ellithy *et al.*, 2011)



(a) Lateral profiles of the calculated and measured magnetic 400kv line.



(b) Lateral profiles of the calculated Magnetic field of 400vk line at rated current

Figure 2.11: Lateral profiles of the magnetic field of 400Kv line at rated current. (Ellithy *et al.*, 2011).

The Figure 2.10 above, shows that the highest magnetic field appears at the center-line of the power line. In comparison with the calculated and measured value is also presented in the form profile as shown in Figure 2.11

2.4 Magnetic field analysis

All alternating electric currents generate electric and magnetic field-collectively known as electromagnetic magnetic fields (EMFs). An overheat line generates an electrostatic field in its vicinity because of the voltage at which it is energized and the charge in its conductors trapped in its capacitance network. In addition, the line generates a magnetic field in it vicinity due to the load current flowing in the conductors (Das Begamudre, 2011). The intensity of the magnetic field is proportional to the currents so that it varies with the load condition.

Power line includes transmission lines and distribution lines. Transmission lines generate both strong electric and magnetic fields. Distribution lines generate weak electric fields but can generate strong magnetic fields use of large scale electrical technologies has led to widespread environmental exposure of EMF over wide frequency range (Singh *et al.*, 2008) . Although all electrical technologies produce environmental EMF, those operating at high power levels, produce exceptionally strong fields. This include high voltage power lines used for long distance transport of electricity operate at 50 Hz, although DC transmission lines exist in some region such from north of Malaysia to Thailand. Line voltages range up to 500 KV, although some experimental lines operate at 1000 KV or higher.

There are two major laws governing electromagnetic fields which are Biot-Savart's law and Ampere's law. Biot-Savart's law of magnetic while Ampere's law is a special case of these two laws of electromagnetic fields is stated in this chapter.

2.4.1 Biot-savart's law

Generally, the electrical and magnetic fields were coupled together as necessity to solve Maxwell's equation (Garrido *et al.*, 2003). Though if the electrical fields generated by power lines are coupled together, in many cases and under certain conditions, some approximations can be assumed and electrical and magnetic fields calculated in an independent way.

This is due to the large wavelength associated with 50 Hz sources. This is known as quasi-static approximation (Olsen, 1994). This means that they can have different magnitudes and directions at different points in space and time.

The most common approach to the calculation of magnetic flux density strength generated by a power lines is based on the Biot-Savart's law (Hayt & Buck, 2012). It states that the differential magnetic field intensity dH produced at point P .

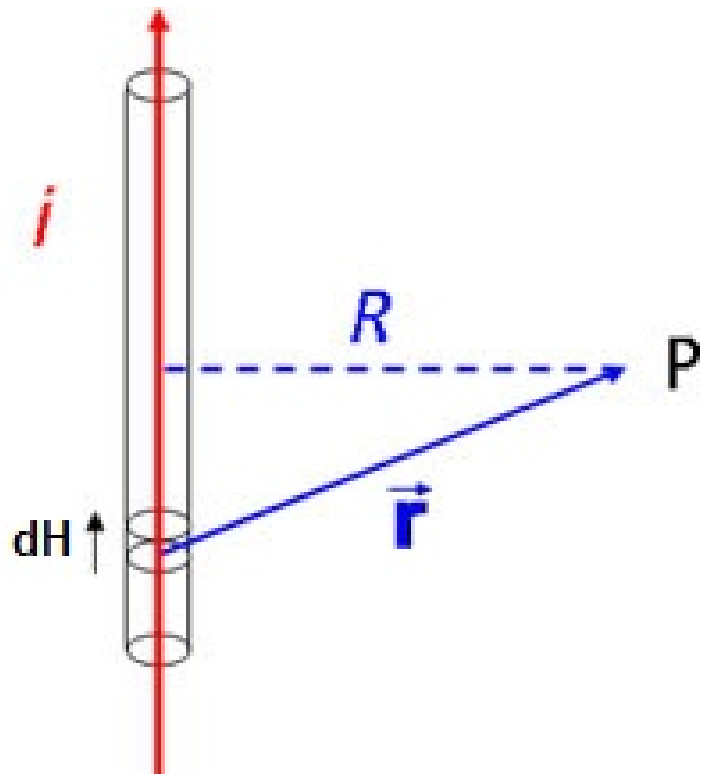


Figure 2.12: Biot-Savart's Law representation

2.4.2 Ampere's Circuital Law

Ander Marie Ampere in 1826 has discovered his own law which called Ampere's Circuital Law. This law relates the magnetic fields to electric current that generate them (its current source). The law can be represented in its differential or integral form . Ampere's Law can also be expressed in an alternative mathematical form that sometimes more convenient to use. The integral will be derived for the case of the long straight wire, then assert without proof that it holds for all configurations. Consider a concentric path of radius R encircling the long straight wire. This law states that the line integral of magnetic fields intensity, H around a path is the same as the net current I_{enc}: enclosed by the path (Sadiku, 2001).

In other words, the circulation of H equals I_{enc}: that Is expressed in a mathematical expression of Eq. (2.1) as follow.

$$\oint H.dl = I_{enc} \tag{2.1}$$

Ampere's law is easily applied determine H when the current distribution is symmetrical. Eq. (2.1) always holds regardless of whether the current distribution is symmetrical, but the equation can only be used to determine H only when a symmetrical current distribution exists. Ampere's law is a special case of Biot-Savart's law.

The application of Ampere's law is various. It is used to determine magnetic field intensity H for some symmetrical current distribution. Some of the application includes a line. For the purpose of this research, only the application of Ampere's law in infinite line current will be taken into consideration.

An infinity long filamentary current I along the z-axis in order to determine H at on observation point P, a closed path is allowed to pass through P this path which Ampere's law is to be applied, is known as 'Amperin' path (Sadiku, 2001). A concentric circle is chosen as the Ampere path , which shows that H and P are constant. Since the path is enclosed, the current I according to Ampere's law is:

$$I = \int H_\phi a_\phi.\rho d_\phi a_\phi = H_\phi \int \rho d_\phi = 2\pi\rho.H_\phi \tag{2.2}$$

This equation can be further simplified and Eq. (2.3) as below is derived.

$$H = \frac{1}{2\pi\rho} a_\phi \tag{2.3}$$

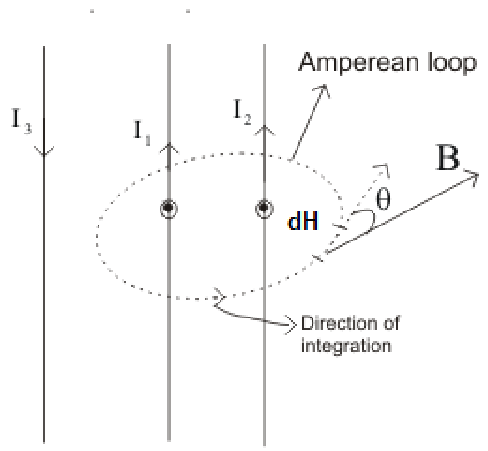


Figure 2.13: Ampere's law applied to a loop

2.4.3 Maxwell's equation

Where I is the current flowing in an elemental dl of a conductor, r is the radial distance, u is a unit vector along the radial direction and ∂H is the contribution to the magnetic field at radius$r$ due to the current element Idl. From this equation, the relationship of B-field can be found using equation 2.4.

$$B = \mu_o H \tag{2.4}$$

The B-field magnitude on the power line is divided into three components that X, Y and Z Components. The magnitude of B-field is given in the equation below;

$$B = \sqrt{B_x^2 + B_y^2 + B_z^2} \tag{2.5}$$

Generally, the magnetic or B-field power line generated by the motion of electric charges (Standard, 1998). The B-field or magnetic flux density is characterized by symbol B and the unit is Gauss (G). The B-field levels near the overhead power transmission line are typically in the range of mG. The magnetic field form transmission power line was oriented in such way that it lies in a plan which is orthogonal to the conductor, as shown on Figure 2.14.

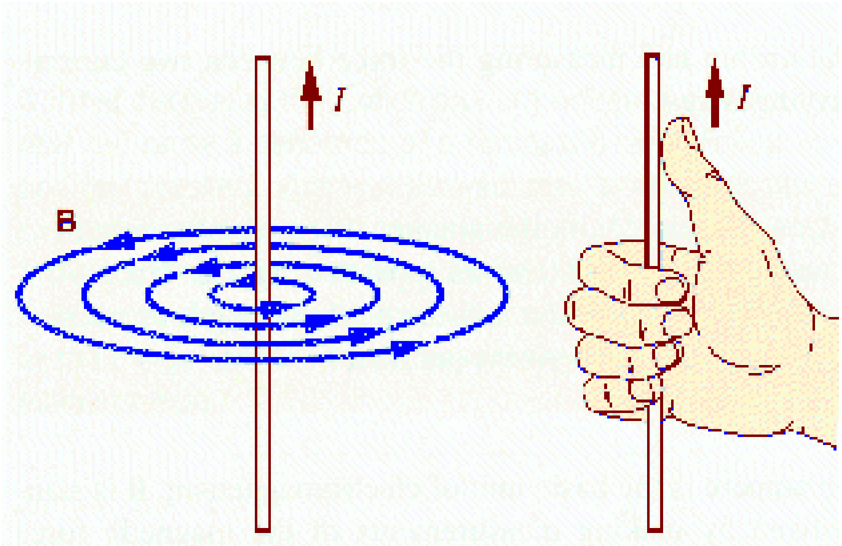


Figure 2.14: B-field direction orientation around a conductor carrying an AC current and magnetic flux representation in the right hand rule.

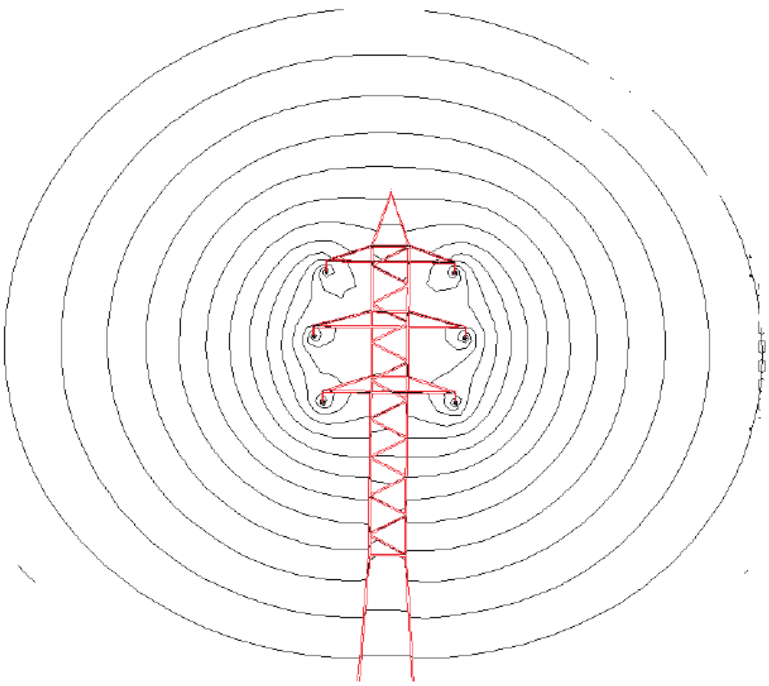


Figure 2.15: Distribution of magnetic field lines around the 110 kV line(Medve, 2012)

2.5 Electric and magnetic fields exposure safety levels

In recent years, there are complaints that exposures to power frequency MFs can potentially cause various types of negative health effects. In sight of the epidemiological studies, however, the possibility remains that intense and prolonged exposures to MFs may increase the risk of leukemia in children. In June 2007 the WHO reported on the possible health effects of exposure to electric and magnetic fields. A number of national and international organizations have formulated guidelines establishing limits for occupational and general public EMFs exposure. Among these organizations are the ICNIRP , IEEE and the NRPB guidelines. In particular, ICNIRP develops guidelines for the safety exposure of workers and the general public to different kinds of non-ionizing radiation, including EMFs. These guidelines are based on established scientific literature, and are developed following well defined steps and criteria. ICNIRP and IEEE standards organizations have been widely accepted and implemented in many countries including CHAD and Malaysia. In the summary section, WHO state that, "Only the acute effects have been established and there are two international exposure limit guidelines (ICNIRP and IEEE) designed to protect against these effects".

The measurements were conducted at 1 m above ground in line with IEEE recommendations (Standard, 2008). In this study, the MFs measurements were made using the 50Hz EMDEX II magnetic field meter and Linear Data Acquisition (LINDA) system and computer programs developed by EPRI (Standard, 1998) ,(Standard, 2008). The resulting levels of MFs are presented in a variety of graphical format. The measured magnetic fields levels will be compared with the levels recommended by ICNIRP international standards see Table 2.1 (Ellithy, 2011).

Table 2.1: Reference levels from ICNIRP standards

(a) 1998(Standard, 1998)

	Occupational	General Public
Frequency (Hz)	50/60	50/60
Magnetic Field μT)	500	100
Electric Field (Kv/m)	10	5

(b) 2010(ICNIRP, 2010)

	Occupational	General public
Frequency (Hz)	50/60	50/60
Magnetic Field (μT)	1000	200
Electric Field (Kv/m)	10	5

We know that $1\mu T = 10mG$ so the maximum limit according to ICNIRP (2010) is : $1000\mu T = 10$ Gauss for occupational and 200 $\mu T = 2$ Gauss.It is clear that the limit has double as shown in Table 2.1a and Table 2.1b.This doubling of the reference value is contradictory to the ongoing discussions of many medical scientists, which typically claim a decrease of the limits to values i.e. 0.2, 0.4,1, 3 or 10 μT for long time exposure for places with high requirements (e.g. kindergartens, schools, playgrounds, bedrooms).(Friedl *et al.*, 2011).

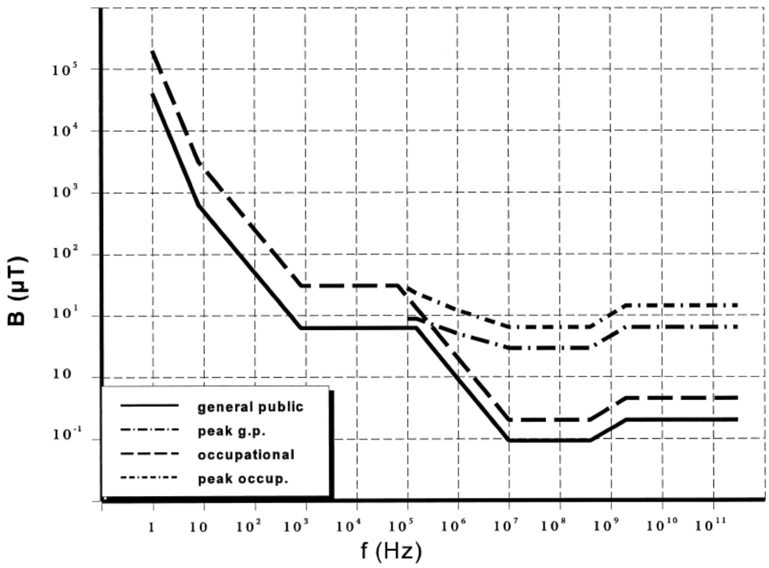
Besides publication on scientific studies, there are also reviews prepared by scientific bodies and government authorities. One of such study was conducted by the International Commission on Non Ionizing Radiation Protection (ICNIRP), an independent scientific organization formed at the Eighth International Congress of the IRPA in 1992 and since then been adopted by many countries including the international EMF project of the WHO. Generally accepted guideline has been established for safe public exposure to power frequency magnetic fields.

ICNIRP has set the limitations guideline based on two categories namely for the general public and occupational exposure line. The occupationally exposed population consists of adults how are generally exposed under known conditions and are trained to be aware of potential risk and to take appropriate precautions. By contrast, the general public comprises individuals of all ages and of varying health status, and may include particularly susceptible groups individuals. In many cases, member of the public are unaware of their exposure to EMF. Moreover, individuals members of the public cannot reasonably be expected to take precautions to minimize or avoid exposure. It is these considerations that underline the adoption of more stringent exposure retractions for the public than for occupationally exposed population. Figure 2.16 shows the flow of the guideline made by ICNIRP.

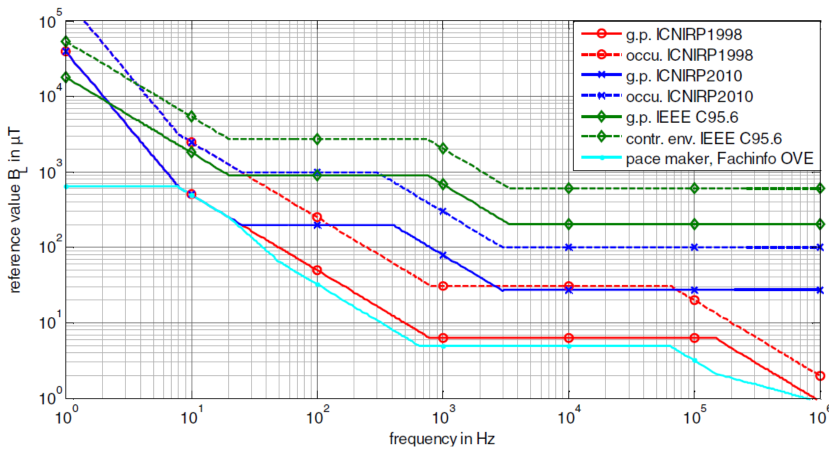
Clearly the exposure limits based on this criterion are some three orders of magnitude greater than those contemplated in the United States and Sweden, based on epidemiological studies. The IRPA/INIRC concludes that association between cancer incidence and 50/60 hertz field exposure is still not established and remains a hypothesis (Holtzhausen & Vosloo, 2010).

Other effects investigated include miscarriages, Alzheimer's disease and depression. In spite of all the studies that have been carried out over the past thirty years there is still no persuasive evidence that the fields pose any health risks. The result obtained show that if there are any risks, they must be very small.

It is also believed but not proved with certainty that the power-frequency



(a) INCIRP guideline flow for limiting exposure (Standard, 1998)



(b) INCIRP guideline flow for limiting exposure(ICNIRP, 2010)

Figure 2.16: Reference levels for exposure for magnetic fields

magnetic field induces a voltage in the tissue which in turn yields a current flow due to the electrical conductivity of the tissue (about 0.1 to 0.2 Siemen/meter). Some workers discount this theory because the cell walls are made from proteins which act as insulation barriers to the current flow. Moreover, the energy fed by this mechanism is considered too low, below even the thermal or Johnson noise of the ions in the cell at the body temperature (37°C or 310°K). Therefore, other mechanisms are sought for to explain the influence of magnetic fields on cancer-producing conditions.

Some international organizations such as the WHO, IRPA as well as other national organizations of different countries have given guidelines for limiting the magnetic field in homes or in occupations such as line workers. In homes where children and adults live and the electrical wiring carries power-frequency current, the resulting magnetic field experienced continuously has been suspected to cause cancerous conditions in the occupants. This observation was published in medical, biological and electrical literature for the first time in North America in 1979 by two scientists in Denver City, Colorado State, U.S.A. Their names are Nancy Wertheimer and Edward Leeper, the former a psychiatrist with the Denver Department of Public Health and the latter a physicist. Prior to that date in 1966, two Russian scientists had published their report on their findings that electricians working with electrical distribution lines — both males and females — experienced breast cancer. They suspected the magnetic field of the current-carrying lines to be the primary cause and advised the government to limit the exposure of workers to the magnetic field (Begamudre, 2006). Since then many international and national organizations have suggested the same limits. This is known as an "occupational hazard".

In case involving the general public, the exposure is about 1 to 2 hours per day in public places where nearby distribution lines can give rise to exposure to magnetic fields. Also, in many countries, schools and shopping centers are located near high-voltage transmission lines and have been suspected as causing cancerous conditions in the school-children and shop-workers. There are many such instances of magnetic fields at power frequency being associated, along with other causes, with cancer-producing circumstances. According to the WHO and IRPA Guidelines, any cancerous or other internal health defects inside the body can only be diagonalized by observing conditions on the surface of the body or by other diagnostic examinations (Begamudre, 2006).

2.6 Biological effects of electromagnetic fields

2.6.1 Biological effects of electric fields

Electric fields are present whenever voltage exists on a line conductor. Electric fields are not dependent on the current but voltage. Electric substations produce EMFs, in a substation, the strongest fields are located around the perimeter fence, and come from transmission and distribution lines entering and leaving the substation. The strength of fields from apparatus that is located inside the fence decreases rapidly with distance, reaching very low levels at relatively short distances beyond substation fences.

The magnitude of the electric field is a function of the operating voltage

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