MAGNETIC FIELD CALCULATION ON THREE PHASE TRANSMISSION LINE USING MAXWELL'S EQUATION IN MATLAB

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DECLARATION

I declare that this thesis entitled "Magnetic Field Calculation On Three Phase Transmission Line Using Maxwell's Equation in MATLAB" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : --

Name : --

Date : --

APPROVAL

I hereby declare that I have checked this report entitled "Magnetic Field Calculation On Three Phase Transmission Line Using Maxwell's Equation in MATLAB" and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Electrical Engineering with Honours

Signature : ....

Supervisor Name : ....

Date : ....

DEDICATIONS

To my beloved father, and the whole family for their long-lasting love, sacrifice and support

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ABSTRACT

Magnetic fields are generated by electric currents, which can be distributed in the space around wires. Thus, it will be generated wherever electricity or electrical hardware is being used. The magnetic field is broadly utilised all through modern technology, particularly in the field of electrical engineering and electromechanics. So, a few people are worried that daily exposure to a magnetic field may impact human's wellbeing. Transmission line are considered as one of the main sources of the magnetic field. As the commitment to the appraisal of expected biological hazard from exposure to power line magnetic field, in the paper, magnetic field distributions under 500KV power transmission lines are investigated. This project is conducted to calculate the existence of magnetic field on 500KV transmission lines in Malaysia. The calculation has been done using the specified software package. The software used is MATLAB Function. As indicated by past researches, the highest permissible magnetic field is 0.04µT for small animal and around (4-100) µT for humans. By utilizing the specific software package and based on the maximum permissible magnetic field, safe margin around the transmission line has been distinguished.

ABSTRAK

Bidang magnet dijana oleh arus elektrik, yang boleh dilihat secara langsung disekitar wayar. Oleh itu, ia akan dijana di mana sahaja perkakas elektrik atau elektrik sedang digunakan. Medan magnet digunakan secara meluas melalui teknologi moden, terutamanya dalam bidang kejuruteraan elektrik dan mekanik elektro. Oleh itu, beberapa orang bimbang bahawa pendedahan harian terhadap medan magnet boleh memberi kesan kepada kesejahteraan manusia. Talian penghantaran dianggap sebagai salah satu sumber utama medan magnet. Sebagai komitmen terhadap penilaian bahaya biologi yang dijangkakan dari pendedahan kepada medan magnet medan magnet, di dalam medan kertas medan magnet di bawah talian penghantaran kuasa 500KV diselidiki. Kertas ini dijalankan untuk mengira kewujudan medan magnet pada talian penghantaran 500KV di Malaysia. Pengiraan telah dilakukan menggunakan pakej perisian yang ditentukan. Perisian yang digunakan adalah MATLAB. Seperti yang ditunjukkan oleh penyelidikan lepas, medan magnet yang dibenarkan adalah 0.04μT untuk haiwan kecil dan sekitar (4-100) μT untuk manusia. Dengan menggunakan pakej perisian tertentu dan berdasarkan medan magnet maksimum yang dibenarkan, jarak selamat di sekitar talian penghantaran telah dibezakan.

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CHAPTER 1

INTRODUCTION

1.1 Overview

The Magnetic Field Calculation on Three Phase Transmission Line Using Maxwell's Equation in MATLAB project is to calculate the magnetic field around the 500 KV transmission line in Malaysia using the algorithm in MATLAB. This Chapter will discuss the background of the project, objectives, scope and problem statements of the project.

1.2 Background

A magnetic field is a vector field that explained the magnetic impacts of electrical currents and magnetized materials. In our life, the effects of magnetic fields are most effortlessly looked with a close-by permanent magnet, which pull on magnetic material such as iron and attract or repel another magnet. The magnetic field surrounding a conductor are created by electric current. The magnetic field applies forces on close-by moving electrical charges and torque on close-by magnets. Furthermore, a magnetic field that changes as indicated by area applies a force on magnetic materials. Both the strength and direction of magnetic field relative with the area. Accordingly, it is a case of a vector field.

The magnetic field is delivered by electric currents and the characteristic magnetic moment of rudimentary particles related with a principal quantum property, their turn. Magnetic field and electrical field are interrelated. Both of them are part of the electromagnetic force, one of the four central forces of nature.

Magnetic field is broadly utilized all through modern technology, especially in the field of electrical engineering and electromechanics. Rotating magnetic fields are normally utilized in electric motor and generators. The connection of magnetic fields in electric devices, for example, the transformer is studied in the discipline of the magnetic circuit. Magnetic forces give data about the charge bearers in a material through the Hall Effect. The earth delivers its magnetic field; it shields the earth's ozone layer from the sun-powered breeze and is vital in route utilising a compass.

1.3 Problem Statement and Motivation

Today, due to the rapid development in our country, the new transmission line is built across Malaysia. Our concern here is the magnetic field emission due to current flow in the transmission line. The magnetic field is delivered whenever electricity is utilized, as it were when there is a flow of current in the conductor. The effect of the magnetic field might be exposed to the health of people living nearby since transmission line are considered as one of the main sources of the magnetic field. The generated magnetic field might also affect the equipment compatibility within the system.

1.4 Objective

The objectives of this project are:

1. To calculate the magnetic field induced by current flow in three-phase transmission line using mathematical calculation method.
2. To apply the Biot-Savart Law in Matlab software.
3. To determine the hotspot of magnetic distribution in the substation environment to help for substation refurbishment or substation designing.

1.5 Scope

The scopes of this project are:

1. The 500KV transmission line which double circuit with eight bundles is selected.
2. MATLAB software will be used to develop the algorithm.
3. The magnetic field (B/H) due to the current flow in the substation.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter will discuss the literature studies and researchers that have been made to improve my understanding of the project. The literature studies and research are gathered from the journal, thesis or internet. The literature studies are important to understand the fundamental of the project and the related information regarding the project.

2.2 Effect of Magnetic Field to Equipment Compatibility

Magnetic field will be generated when electrical equipment is in use, magnetic field of transmission line cause electrical currents flow inside any equipment in the field zone, so a few people concern that magnetic fields may influence on the devices in the field zone as equivalent of current transformer, voltage transformer, cables or numerical relays in control room in high voltage substation or vitality meters which will case error and low of accuracy.

This project aims to show a more practical approach on how the value of the most extreme charges are gotten from the overhead line geometric measurement and its most noteworthy evaluated system voltage. Thus, it is clarified how electric field emerges from electric charge and how magnetic fields emerge from the movement of these electric charges.

The magnetic field doesn't directly affect the properties of insulating materials, yet they influence the power system indirectly in the following way, high AC current cause time-differing magnetic fields that induced a voltage in conducting loops. Essentially, high time-varying currents caused by lightning can cause induced voltages. These overvoltage cause high electric fields in the components of the power system that may cause insulation systems failure.

So, the electric and magnetic fields give an impact on all tools in high voltage substation and furthermore affecting on the protection instrument that makes an error on the fault location, the measuring value, and the fault current value.

To diminish the affection of the field:

1. The building for the control room ought to be after the value of the electromagnetic field at least esteem.
2. For the cables by choice of the sort for isolation and cover and sheath earthed in two sides.
3. The instrument transformer ought to be protected by the shield, and it is earthed.
4. Cable plate ought to toss underground cable plate where the ground voltage is zero and underground point which is little point affection by the electromagnetic field.
5. The protection board which fix the equipment can be declined electromagnetic field directly by earthed.
6. The choice of the measuring instrument such as ammeter, voltmeter and wattmeter and the protection equipment's should be covered by metal which is aluminum or copper so it can be connected with earth and steel panel which also can be earthed.

The magnetic field from a power line is differ widely because the current through wires or cable relies on the measured intensity expended. There is two elemental of 50 Hz magnetic field which is passive magnetic field and active magnetic field. The magnetic field relies upon the accompanying elements, the appraisals of current going in the conductors, clearance of the line where maximum magnetic field happens underneath the conductor, and falls quickly with separation on either side, phasing of the conductor like conductor spacing. The induced current might be similar in direction or inverse direction where this will do error in the protection relay or measurement equipment [5].

2.3 Magnetic Field of Three-Phase Transmission Line

Three-phase electric power is a typical technique of alternating-current electric power generation, transmission and distribution. It is a sort of poly stage system that is the most commonly utilized by electrical grids worldwide in exchanging power. The three-phase system can deliver a magnetic field that rotates in an explicit direction. In the three-phase system, each number of circuit conveying its alternating currents with the same frequency which achieve their momentary peak values at one-third of a cycle from each other. The current of the three-phase system can be expressed as follows:

$$I_a = I_m \cos(\omega t + \varphi_a) \quad (2.1)$$

$$I_b = I_m \cos(\omega t + \varphi_b) \quad (2.2)$$

$$I_c = I_m \cos(\omega t + \varphi_c) \quad (2.3)$$

$$\varphi_b = \varphi_a - 120 \quad (2.4)$$

$$\varphi_c = \varphi_a + 120 \quad (2.5)$$

The values of currents in root mean square (RMS) each conductor can be calculated using the equations below.

$$I_{ra} = \frac{I_m}{\sqrt{2}}\cos(\varphi_a) \qquad I_{ia} = \frac{I_m}{\sqrt{2}}\sin(\varphi_a) \quad (2.6)$$

$$I_{rb} = \frac{I_m}{\sqrt{2}}\cos(\varphi_b) \qquad I_{ib} = \frac{I_m}{\sqrt{2}}\sin(\varphi_b) \quad (2.7)$$

$$I_{rc} = \frac{I_m}{\sqrt{2}}\cos(\varphi_c) \qquad I_{ic} = \frac{I_m}{\sqrt{2}}\sin(\varphi_c) \quad (2.8)$$

2.4 Magnetic Field Analysis

An overhead line created an electrostatic field in its region due to the voltage at which it is invigorated and the charge in its conductors caught in its capacitance network. Also, the line produces a magnetic field in its region because of the load current flowing in the conductors. The force of the magnetic field is relative to the current so it can be influenced by the load condition.

There are two types of the power line which are transmission line and distribution lines. Transmission line generates a strong electric field and magnetic field while the distribution line generates powerless electric fields yet can generate a strong magnetic field. The utilization of vast scale electrical technologies has prompted broad environmental exposure of EMF over wide frequency range. Even though all electrical technologies produce ecological EMF, those working at high power levels, create a surprisingly strong field.

There are two major laws of electromagnetic fields, which are Biot-Savart's law and Ampere's law.

2.4.1 Biot-Savart's Law

For the most part, the electrical and magnetic field were paired together to explain Maxwell's Equation. In spite of the fact that if the electrical field produces by power lines are matched together, in many cases and under specific conditions, some estimate can be accepted and electrical and magnetic fields determined in a freeway.

This is because of the extensive wavelength related to 50 Hz sources. This is known as a semi-static estimation. This implies they can have different magnitudes and directions at various points in space and time.

The most common methodology for calculation of magnetic flux density strength by power lines depends on the Biot-Savart's law. It expresses that the differential magnetic field intensity dH delivered at point P.

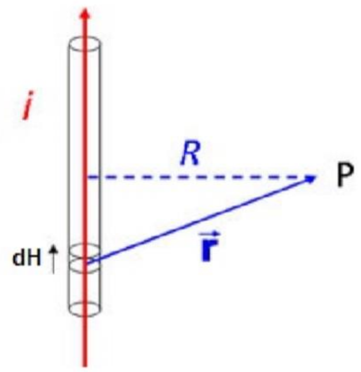

Figure 2.1: Illustration of Biot-Savart Law [2]

2.4.2 Ampere's Law

Ampere's Law is a helpful law that relates the magnetic field along a closed loop to the electric current going through the loop discovered by Andre-Marie Ampere in 1826 [1]. This law can be expressed in its differential or integral form. Ampere's Law can likewise be expressed in a different mathematical form that some point lot less demanding to utilize [2]. This law express that the line integral of magnetic fields intensity, H around a path is equivalent with the net current encased by the path, I_{enc}.

As such, the dissemination of H equal I_{enc} that is represented in a mathematical expression as follow:

$$\oint H.dl = I_{enc} \qquad (2.9)$$

By applying Ampere's Law, H can easily determine when the current distribution is symmetrical. Ampere's Law is a rare instance of Biot-Savart's Law [1]. The utilization of Ampere's Law is miscellaneous. It is utilized to determine magnetic field intensity, H for some symmetrical current conveyance. A portion of the application incorporates a line.

The magnetic field of a vastly long straight wire can be gained by applying Ampere's Law. The magnetic field generated by a single wire is equivalent to the following equation.

$$H= \frac{1}{2\pi\rho} a_{\emptyset} \qquad (2.10)$$

2.4.3 Maxwell's Equation

Where I represent current flowing in an element dl of a conductor, r is the spiral separation, u is a unit vector along the radial direction and ∂H is the contribution to the magnetic field at radius r because of the current element I dl. Based on this condition, the relationship of B-field and H-field can be discovered by the equation below.

$$B = \mu_{\circ}H \qquad (2.11)$$

The B-field magnitude on the power line can be separated into three components which x, y and z components. The magnitude of B-field is expressed by the following equation.

$$B = \sqrt{B_x^2 + B_y^2 + B_z^2} \qquad (2.12)$$

Principally, the magnetic flux density of the power line is produced when there is a movement of electric charge [2]. The magnetic flux density is portrayed by symbol B and the unit is Gauss (G). The magnetic flux density levels close to the overhead power transmission line are normally in the range of mG. The magnetic field form transmission line was situated in such a way that it lies in a plan which is orthogonal to the conductor.

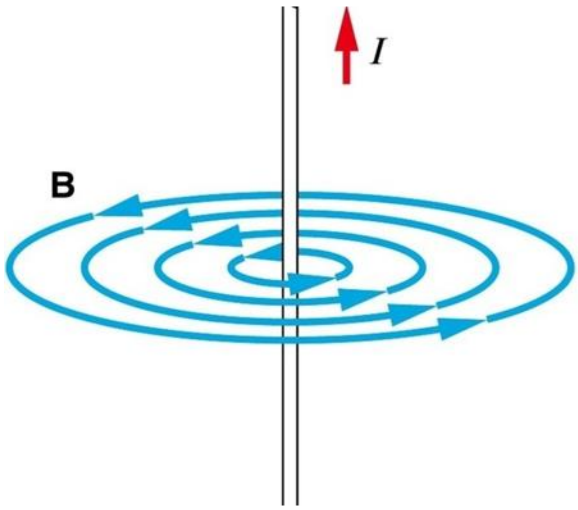

Figure 2.2 : Magnetic flux density orientation around a conductor conveying an AC current and magnetic flux illustration in the right-hand rule [2]

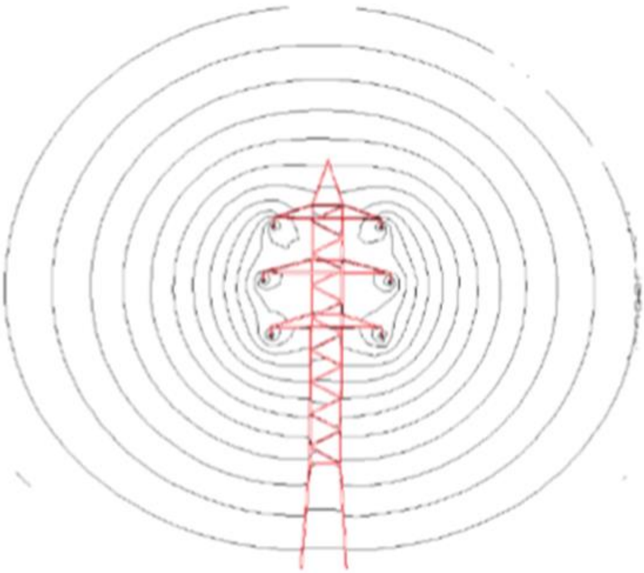

Figure 2.3 : Circulation of magnetic field around the transmission line [2]

2.5 Software Package

MATLAB is presently accessible on PC for engineering applications. Magnetic field around three phase's system can be determined by using a software package developed in MATLAB. A few parameters, for example, current of the conductor (wire), tallness of transmission towers, and diameter of wires and position of the phases in transmission tower are the parameter of this software. By using the parameter and depending on condition, the magnetic field around three phases system at a constant height from the ground or in a settled width of the transmission tower can be determined.

2.6 Magnetic Fields Analysis under High Voltage Ac Transmission Line

As a result, underground distribution line also produces electric and magnetic field [3]. The magnetic field cannot be shielded, and it can pass through non-metallic material [1]. However, the electric field can be shielded trees, fence, concrete building etc. [3]. The electric field and magnetic field are normally stronger near the conductor and become weaker rapidly as the distance from sources is increasing [1]. According to the previous study, the maximum acceptable exposure to the magnetic field for a small living organism is 0.04μT and for a human is about (4-100) μT [4].

Electric and Magnetic Fields strength influences by the following factors,

1. Height of conductors above the ground.
2. The radius of conductors. The symmetrical phase of the conductors
3. Position of the conductor concerning other conductors.
4. Position of estimating point regarding conductor positions.
5. The electric field mainly relies upon the magnitude of the conductor voltage, and the magnetic field relies upon the magnitude of the conductor current.

The magnetic field produced by transmission line is quite uniform over the ground. Calculation of the magnetic field depends on some of the suppositions; for example, the earth is assumed to be flat, the conductor is assumed to be parallel to each other and parallel to the earth surface. The current assumed to be as balanced current, which means the magnitude of the current is the same in all phase, this is commonly possible when the load are maintained in balance under operation on all phase.

2.6.1 Magnetic Fields Analysis on 132 KV Double Circuit Transmission Line

In this paper, the magnetic field was computed around three phases double circuit 132 KV transmission line [4]. The lattice tower structure is shown in the figure. The magnetic field at any point of interest in the Cartesian coordinate plane can be computed, on considering the focal point of transmission line tower as reference axis (0, 0). The focal point of the tower at ground parallel to the point X=0, Y=0.

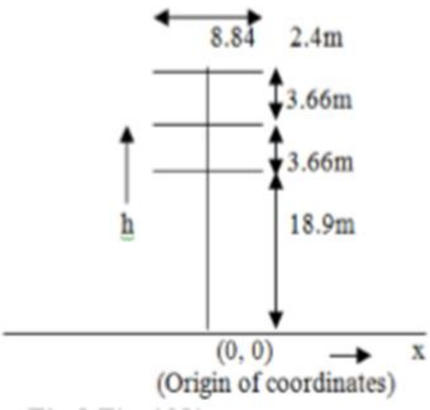

Figure 2.4: The 132 KV tower structure [3]

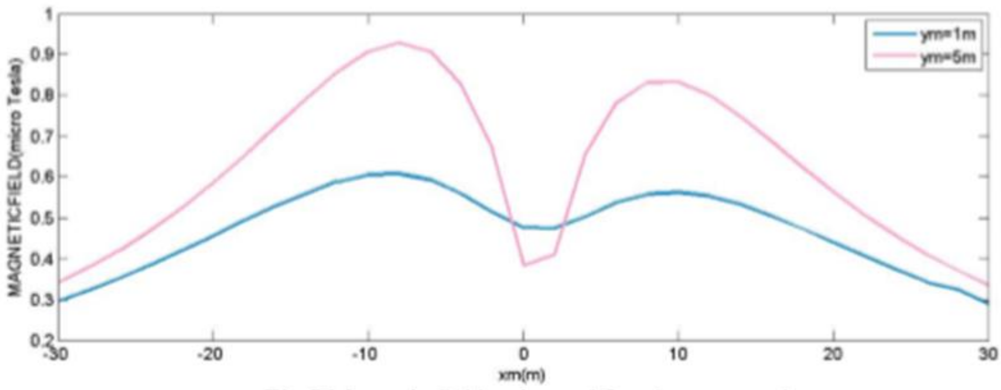

Figure 2.5: Magnetic field at 1m and 5m above ground [3]