MAGNETIC FIELD SIMULATION & MEASUREMENT OF UNDERGROUND CABLE SYSTEM INSIDE DUCT BANK

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ABSTRACT

In Malaysia there is no regulation on the limit of Electromagnetic Field or EMF yet. However there is a rise of public awareness on this issue. Before this people are always concern about the overhead cables. No study was done for underground cables which are installed 0.6 m to 1.5 m deep in the ground. This paper presents the resultant of the EMF from the underground cable installed inside duct bank.

INTRODUCTION

This study is divided into two parts which are EMF field measurement and simulation. The field measurement were done using three-axis meter i.e. EMDEX II Meter and LINDA Wheel as shown in Figure 1. The simulations were done using EMCALC.

Assuming that underground cables are buried underground and neglecting any shielding effect, the evaluation of magnetic field from underground cable is similar to evaluating magnetic field from overhead transmission lines.

Magnetic fields are generally affected by a number of variables including [1]:

(i) Magnitude of phase current
(ii) Distance of cables from ground
(iii) Phase configuration
(iv) Lateral distance from underground cables.

Figure 1: EMDEX II Meter and Linear Data Acquisition (LINDA) Wheel

(i) Magnitude of Phase Current [2]

At power frequency, the magnetic field is proportional to the magnitude of the phase current. Hence it is crucial to know the amount of current flowing through the cable.

(ii) Distance from ground [2]

Since magnetic fields decrease with increase distance from the source, increasing the depth of underground cables will reduce the magnetic fields at ground level.

(iii) Conductor Phase Configuration [2]

Generally underground cables are either single core or three cores. The ground level magnetic field is the sum of the fields produced by the currents in all three phases of the circuit and is dependent upon the distance between the observer and each current carrying cable. Placing the three phases as close together as possible creates greater field cancellation and the magnetic field at ground level is reduced.

(iv) Lateral Distance [2]

Magnetic field strength decreases with the lateral distance from the source of the magnetic field.

FIELD MEASURMENT

Measurements of magnetic field were done on existing underground cable system in Putrajaya at the following locations:

(i) PPU PJ13
(ii) PPU CJ6

The cable systems at PPU-PJ13 and PMU-CJ6 were underground cables laid inside duct bank.

For this study, procedure for the measurement of power frequency magnetic fields from alternating current (AC) underground cables was developed. These procedures were adapted from the IEEE STD 644-1994: *IEEE Standard Procedures for Measurement of Power Frequency Electric and Magnetic Fields from AC Power Lines.* The magnetic fields were measured at a height of one meter above ground level. Field meters with three-axis probes were used to measure the resultant magnetic field.

The results are shown in Figure 2 and Figure 3 for PPU PJ13 and PPU CJ6 respectively. Maximum EMF found was 23mG.

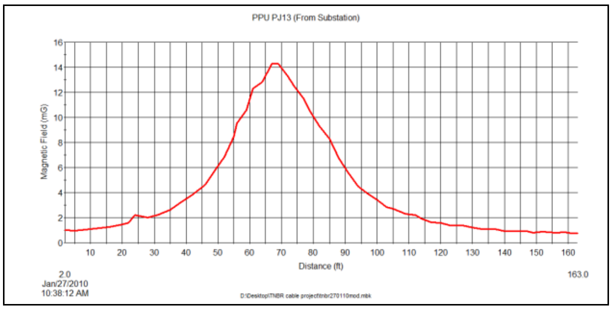

Figure 2: EMF Results for PPU PJ13

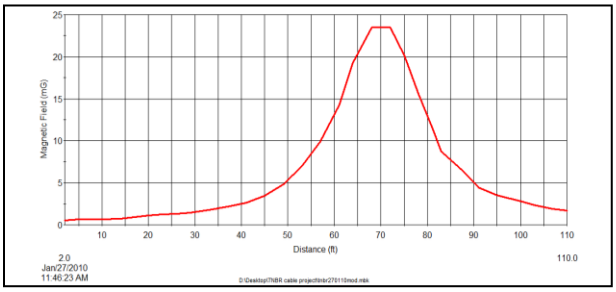

Figure 3: EMF Results for PPU CJ6

SIMULATION

Besides measurement, simulation was done to verify the measurement results using EMCALC 2000 (FIELDS program).

The EMCALC program is developed by Southern California Edison (SCE) to calculate and plot the magnetic and electric fields produced by transmission and distribution lines.

The FIELDS program utilizes the basic algorithms for the calculation of electric and magnetic fields listed in EPRI's Transmission Line Reference Book. The electric field calculation assumes earth as a perfect conductor and sums the vector components of the field created by the charge on each conductor. Likewise, the magnetic field calculation performs a vector sum of the contribution to the field from each of the conductor currents. FIELDS calculates both the square root of the sum of the squares of the vertical and horizontal field components and also the maximum phasor component based upon the magnitude of the major semi-axis of the field ellipse.

The simulation was done using the loading for each cable at the time measurement was done. The comparison between simulated and measured magnetic field are shown in Figure 4 and Figure 5 for PPU PJ13 and PPU CJ6 respectively.

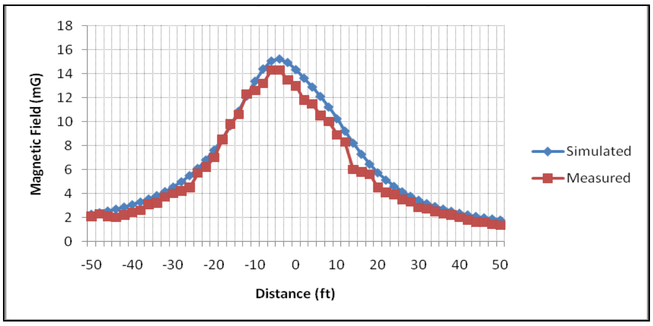

Figure 4: Comparison of Measured and Simulated Magnetic Field for PPU-PJ13

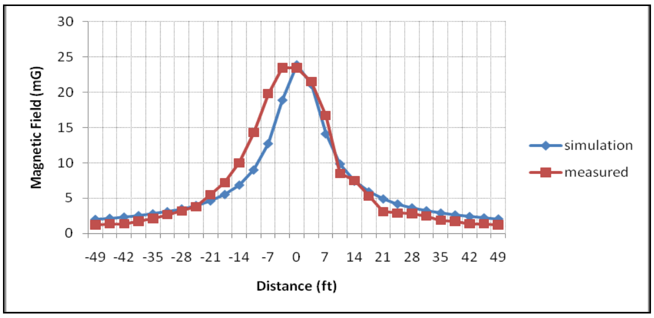

Figure 5: Comparison of Measured and Simulated Magnetic Field for PPU-PJ13

Since the measurement for both substations were verified, magnetic fields due to cables at full load current could be estimated. The simulation results are as shown in Figure 6 and Figure 7.

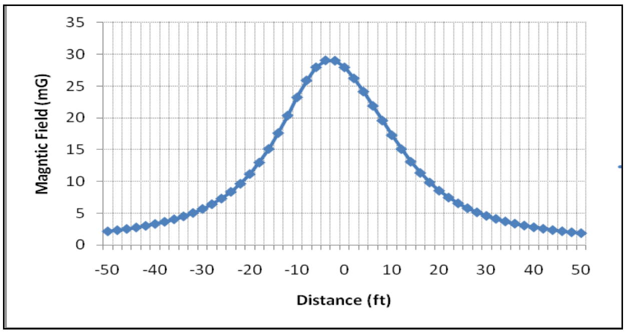

Figure 6: Simulated Magnetic Field for PPU PJ13 at full load condition

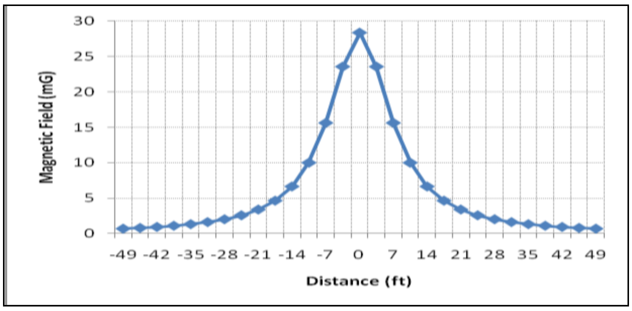

Figure 7: Simulated Magnetic Field for PPU CJ6 at full load condition

RESULTS AND DISCUSSION

Since magnetic field from underground cables are characterized by high maximum values and rapid decay of magnetic fields with distance, Table 1 shows the summary of results obtained from the simulation studies showing maximum magnetic fields from each cable system and distance from the center of the duct bank where magnetic field had decayed to 3mG. An arbitrary value of 3mG was chosen to provide rough indications of the decay rate and as an indication of the distance involved when considering adoption of precautionary principles.

Table 1: Summary of Maximum Magnetic Fields from Each Cable System and Distance from the Center of the Duct Bank

Configuration	Maximum (mG)	Distance from peak when magnetic field is 3mG (ft)	
		Left	Right
PPU PJ 13	29.1	42	38
PPU CJ 16	2.8	nil	Nil

PPU CJ16 gave the lowest magnetic field. This is because the cables were packed close together.

Maximum magnetic field for PPU-PJ13 can be reduced by placing the cables closer together and rearranging the conductor phase arrangements as shown Figure 8 while the load current remained the same. From the simulation it can be seen that maximum magnetic field can be reduced by 82.1% from 29.1mG to 5.2mG as shown in Figure 9.

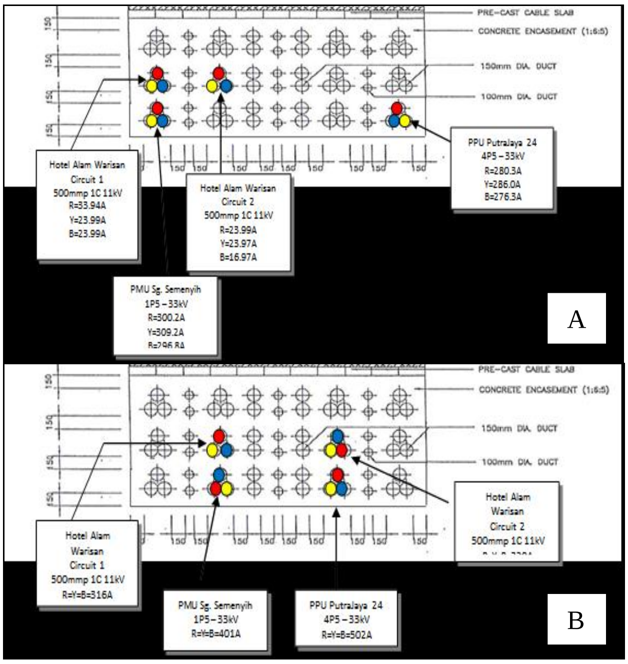

Figure 8: A is Actual Conductor Phase Arrangement and B is Recommended Conductor Phase Arrangement

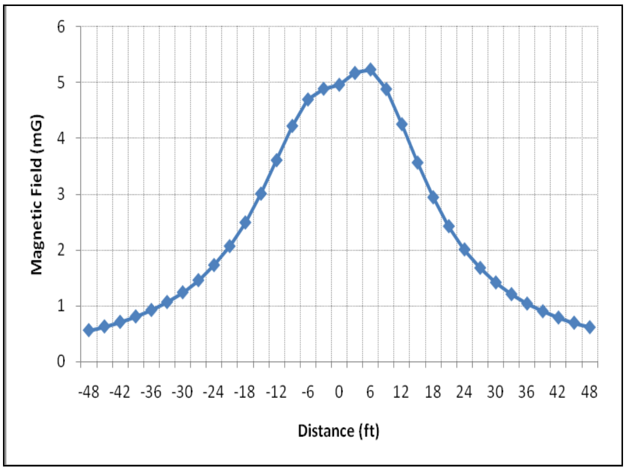

Figure 8: Magnetic Field Profile for Alternative Cable Arrangement for PPU-PJ13

CONCLUSION

Magnetic field measurements from underground cables had been conducted at two locations. The highest magnetic field was found to be 23mG. Simulation models of the underground cable systems were developed and verified. Magnetic field simulation studies were then carried out for the cable systems with full load condition. In the simulation studies, maximum magnetic field was found to be much lower than the exposure limit recommended by WHO and ICNIRP, which is at 1000mG for the general public and 5000mG for workers.

ACKNOWLEDGMENT

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