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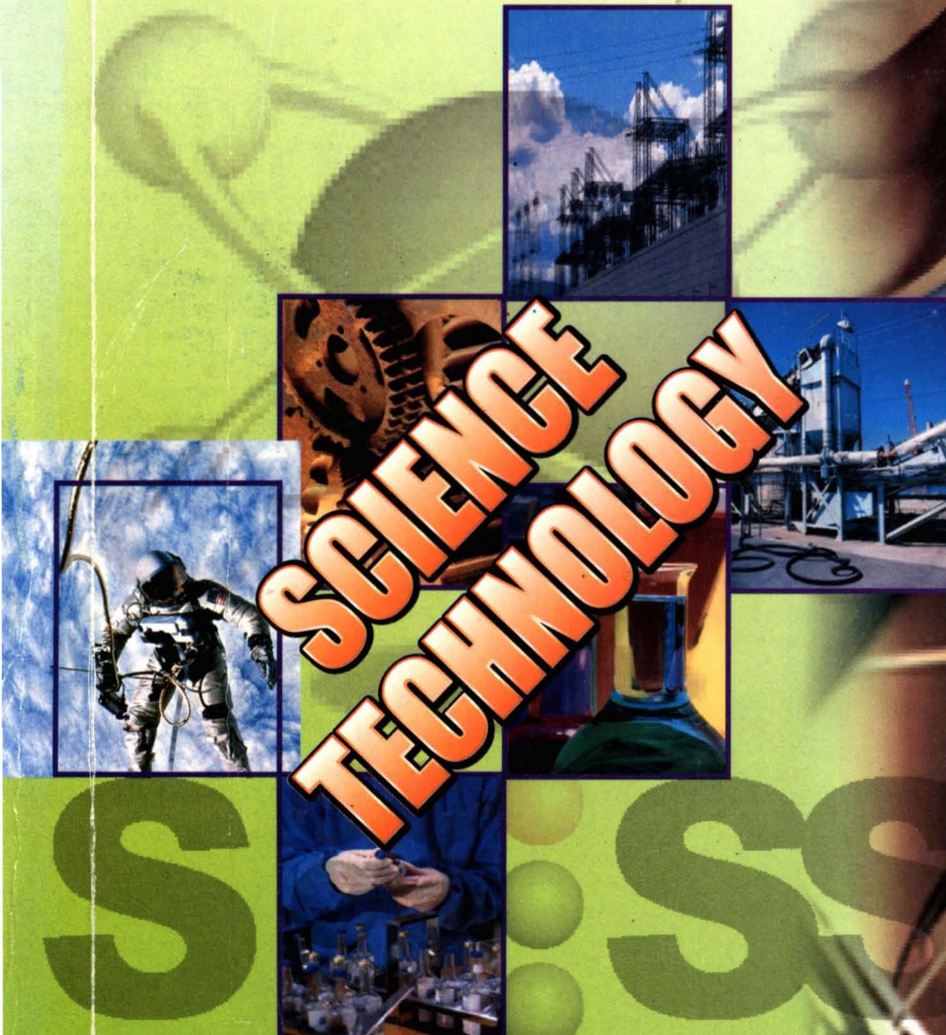

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Management of Magnetic Field from Quadruple Tower Transmission Lines

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ABSTRACT

Electric and magnetic fields exists whenever electricity is generated, transmitted and used. Recent worldwide attention to the harmful effects of magnetic fields emanating from power lines resulted in a growing motivation to develop methods for management of magnetic field aimed at reducing possibilities of such hazards. To optimize the usage of land, the use of quadruple tower for electric power transmission is on the increase. This paper presents the results of magnetic field simulation studies conducted on the quadruple tower transmission lines currently used in Malaysia. The results of the simulation studies were categorized to indicate the best conductor phase arrangement for lowest peak magnetic field, lowest average magnetic field and lowest magnetic field at the edge of the right-of-way. It was found that magnetic field reduction of more than 90% can be achieved using proper conductor phase arrangement.

Keywords: *EMF health effect, magnetic field reduction, transmission line*

Introduction

There has been a growing public concern in Malaysia on the adverse health effects of electric and magnetic fields produced by electric power transmission lines. The interest of scientific community on the probable adverse health effect of these fields began with a case controlled epidemiological study of childhood leukemia carried out by epidemiologist Nancy Wertheimer and a physicist Ed Leeper in Denver, Colorado. The results of the study were published in 1979 with Wertheimer and Leeper concluding that a statistical correlation existed between childhood leukemia and high magnetic field (Werteimer et al. 1979). No magnetic field measurements were made in the study. Rather than measuring actual magnetic fields, the authors depended on a concept based upon a wire code system that they defined. Exposure to power frequency magnetic field was assumed to be related in some way to the wire code assigned to the power lines in the vicinity. The wire code is based on the thickness and configuration of the electricity distribution line in the vicinity of the child's residence.

Numerous epidemiological studies since then had been carried out to find any relationship between childhood leukemia and power frequency magnetic fields. The results of these studies are varied; some providing relative resemblance to prior studies while others provide conflicting results. In an effort to resolve this controversy, some researchers conducted meta-analysis study, a method that is used to reconcile studies that showed inconsistent results (Ahlbom et al. 2000; Greenland et al. 2000).

Besides reports of studies by research groups, there are also reviews prepared by scientific bodies and government authorities. One 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 International Radiation Protection Agency (IRPA) in 1992. ICNIRP published guidelines for limiting exposures to time-varying electric and magnetic field in 1998 and since then been adopted by many countries including the International EMF Project of the World Health Organization (*International Commision* 1998). ICNIRP is of the opinion that although the results of epidemiological studies provide suggestive evidence of an association between magnetic field exposures and cancer, the induction of cancer from long term EMF exposure was not considered to be established, due to lack of support from laboratory and animal studies. ICNIRP recommended a limit of 1000mG for public exposure to 50 Hz power frequency magnetic field based on short-term, immediate health effects such as stimulation of peripheral nerves and muscles.

Variables that Effect Magnetic Fields from Overhead Transmission Line

The magnetic field of overhead electric power transmission lines are generally affected by a number of variables including: (i) magnitude of phase current (ii) height of conductors above ground, (iii) configuration of conductors (iv) lateral distance from transmission lines.

Magnitude of Phase Current

At power frequency, the magnetic field is proportional to the magnitude of the phase current. The current on a line varies with the demand for electricity. Hence it is not possible to define a single magnetic field level associated with a given point near a transmission line unless the current carried by the line is known or given.

Conductor Height

Since magnetic fields decrease with increase distance from the source, increasing the height of the current carrying conductors will reduce the magnetic fields at or near ground level.

Conductor Configuration

Each phase of a three phase transmission line system has a single or a bundle of two or more conductors. The ground level magnetic field is the sum of the fields produced by the currents in all the conductors and is dependent upon the distance between the observer and each current carrying conductor. Placing the three phases as close together as possible (compaction) creates greater field cancellation and the magnetic field at or near ground level is reduced.

Lateral Distance

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

Quadruple Tower Transmission Lines

Electric power transmission over long distance is normally done via overhead lines. These lines are supported at each span by transmission line towers. The most predominant type of tower configuration used in Malaysia is the double circuit type, which carries two circuits of three phase conductors. The phases of each circuit are arranged vertically on one side of the tower. Quadruple tower is similar to the double circuit tower but with arms that can carry four circuits instead of two. Hence there are two circuits on one side of the tower and the other two on the other side. The top two circuits on the quadruple tower normally carry the 275kV lines while the bottom two circuits carry the 132kV lines. Like the double circuit lines, the phases of each circuit are arranged vertically. Figure 1 shows four circuit overhead lines carried by two double circuit towers erected side-by-side while Figure 2 shows different four circuit lines carried on one quadruple tower.

Overhead transmission lines in Malaysia run within an exclusive corridor known as the right-of-way (ROW). The edge of the corridor is about 20m from the center of either side of the tower. When two transmission towers are constructed side by side, a distance of 20m is also maintained between the two. Hence for a transmission line system that has four circuits carried by double circuit towers (Figure 1), the total width of right-of-way is around 60m, while for the same number of circuits carried by quadruple tower is 40m (Figure 2). An analysis of the magnetic field emitted from different tower configurations had been done (Ismail et al. 2004).

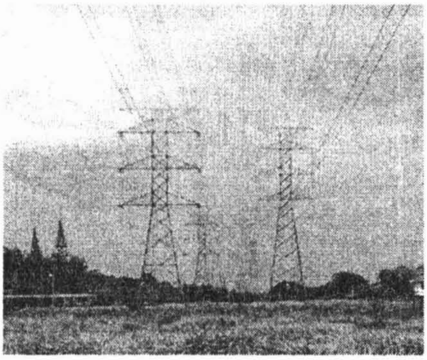

Fig. 1: Two Double Circuit Transmission Line Towers Carrying Four Circuits

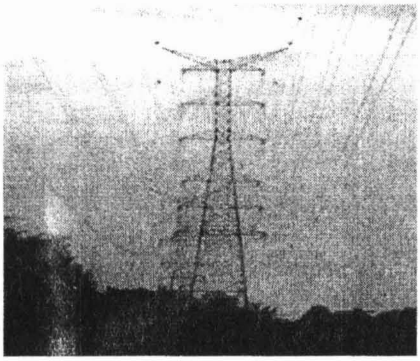

Fig. 2: Single Quadruple Tower Transmission Line Tower Carrying Four Circuits

Simulation Studies

A program had been developed to evaluate the magnetic field density from overhead lines and verified using a 1/40 scaled down model of a transmission line (Rahman et al. 2005). Using the same program, and based on the nominal dimensions of a quadruple tower, simulation studies were conducted to evaluate ground level magnetic field due to change in phase arrangements. Since there are four, three phase circuits on a quadruple tower, 1296 different phase arrangement combinations were considered. For each case, magnetic field density at a height of 3 feet was evaluated for a distance of 100 feet on either side of the centre of the tower with a step size of 2 feet. Table 1 shows a sample of the input data used for simulation. The A, B and C phases correspond to the red phase, yellow phase and blue phase of the conductors respectively. The program produces output in the form of table and graphical form as shown in Figure 3

Table 1: Sample Input Data for Simulation

Phase Name	Phase coordinates (ft)		Phase-Phase (kV)	Phase Current. (Amp)	Phase Angle (Deg)
	Horz	Height			
A1	-19.36	137.8	275	600	0
B1	-19.36	119.09	275	600	240
C1	-19.36	100.39	275	600	120
A1	-15.09	85.47	132	600	0
B1	-15.09	72.34	132	600	240
C1	-15.09	59.22	132	600	120
A2	19.36	137.8	275	600	0
B2	19.36	119.09	275	600	240
C2	19.36	100.39	275	600	120
A2	15.09	85.47	132	600	0
B2	15.09	72.34	132	600	240
C2	15.09	59.22	132	600	120

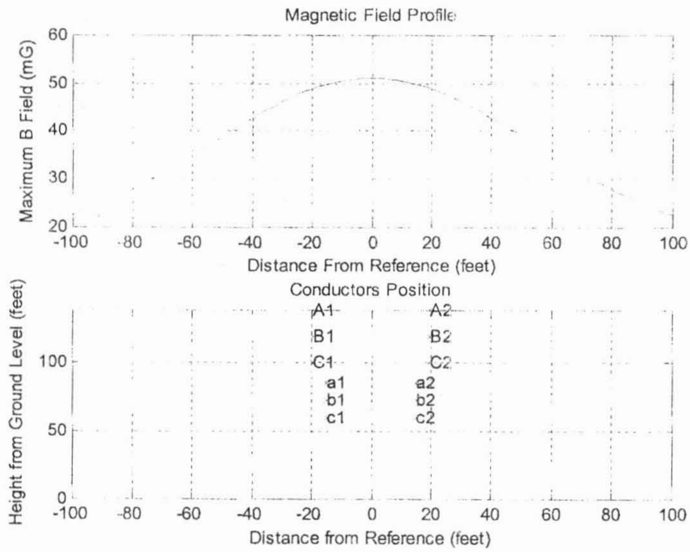

Fig. 3: Graphical Output of Magnetic Field Underneath Quadruple Tower for Case 1

Peak magnetic field and magnetic field at the edge of the ROW were considered and compared. From the simulation studies, four distinct groups were extracted:

- Group 1: Lowest Peak Magnetic Field
- Group 2: Lowest Average Magnetic Field
- Group 3: Lowest Magnetic Field at Edge of ROW
- Group 4: Highest Magnetic Field

Tables 2, 3, 4 and 5 show the results of the simulation studies for the different cases and phase arrangements that are grouped together as group 1, 2, 3 and 4 respectively. It was found that although the phase arrangements of conductors in a group are different, the phase patterns for the same group are the same. This is illustrated in Figure 4. The lines in the pattern indicate conductors having the same phase.

Table 2: Simulation Results for Group 1

Case	Phase Configuration		Left ROW (mG)	Peak (mG)	Right ROW (mG)
	275KV	132kV			
140	ABC-BCA	cba-acb	5.9	9.0	5.5
177	ABC-CAB	cba-bac	5.5	9.0	5.9
311	ACB-BAC	bca-cab	5.5	9.0	5.9
415	ACB-CBA	bca-abc	5.9	9.0	5.5
496	BAC-ACB	cab-bca	5.9	9.0	5.5
637	BAC-CBA	cab-abc	5.5	9.0	5.9
660	BCA-ABC	acb-cba	5.5	9.0	5.9
801	BCA-CAB	acb-bac	5.9	9.0	5.5
883	CAB-ABC	bac-cba	5.9	9.0	5.5
986	CAB-BCA	bac-acb	5.5	9.0	5.9
1120	CBA-ACB	abc-bca	5.5	9.0	5.9
1157	CBA-BAC	abc-cab	5.9	9.0	5.5

Table 3: Simulation Results for Group 2

Case	Configuration		Left ROW (mG)	Peak (mG)	Right ROW (mG)
	275 kV	132kV			
211	ABC-CBA	cba-abc	4.7	9.4	4.7
345	ACB-BCA	bca-acb	4.7	9.4	4.7
603	BAC-CAB	cab-bac	4.7	9.4	4.7
694	BCA-ACB	acb-bca	4.7	9.4	4.7
953	CAB-BAC	bac-cab	4.7	9.4	4.7
1086	CBA-ABC	abc-cba	4.7	9.4	4.7

Table 4: Simulation Results for Group 4

Case	Phase Configuration		Left ROW (mG)	Peak (mG)	Right ROW (mG)
	275 kV	132 kV			
135	ABC-BCA	cab-bac	2.8	19.5	12.9
154	ABC-CAB	acb-bca	12.9	19.5	2.8
294	ACB-BAC	abc-cba	12.9	19.5	2.8
413	ACB-CBA	bac-cab	2.8	19.5	12.9
499	BAC-ACB	cba-abc	2.8	19.5	12.9
632	BAC-CBA	bca-acb	12.9	19.5	2.8
665	BCA-ABC	bac-cab	12.9	19.5	2.8
798	BCA-CAB	abc-cba	2.8	19.5	12.9
886	CAB-ABC	bca-acb	2.8	19.5	12.9
1003	CAB-BCA	cba-abc	12.9	19.5	2.8
1143	CBA-ACB	cab-bac	12.9	19.5	2.8
1162	CBA-BAC	acb-bca	2.8	19.5	12.9

Table 5: Simulation Results for Group 4

Case	Phase Configuration		Left ROW (mG)	Peak (mG)	Right ROW (mG)
	275 kV	132 kV			
1	ABC-ABC	abc-abc	32.7	51.1	32.7
260	ACB-ACB	acb-acb	32.7	51.1	32.7
519	BAC-BAC	bac-bac	32.7	51.1	32.7
779	BCA-BCA	bca-bca	32.7	51.1	32.7
1037	CAB-CAB	cab-cab	32.7	51.1	32.7
1296	CBA-CBA	cba-cba	32.7	51.1	32.7

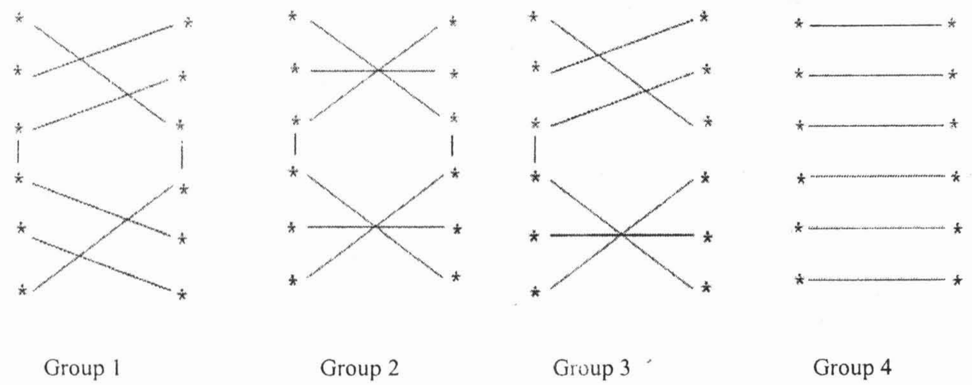

Fig. 4: Conductor Phase Pattern of Each Group

Discussions and Conclusions

The results of the simulation studies extracted above are summarized and shown in Table 6. Using the highest magnetic field produced by group 4 as a base, percentage reduction of magnetic field at the left of ROW and peak magnetic field were evaluated for the other groups. It was found that magnetic field reduction of 91% is possible for the same load carried by the transmission lines by using correct phase arrangement. It is however cautioned that, this study only looks at magnetic field when recommending transmission line phase arrangements. Other factors such as line impedance, system stability, practicality in stringing the lines and others need to be taken into consideration when deciding conductor phase arrangement.

Table 6: Comparison of Magnetic Field for Different Conductor Arrangements

Group	Magnetic Field at Left ROW (mG)	Peak Magnetic Field (mG)	Magnetic Field at Right ROW mG)	Percentage Reduction of Magnetic Field at Left ROW (%)	Percentage Reduction of Peak Magnetic Field (%
1	5.9	9.0	5.5	82.9	82.4
2	4.7	9.5	4.7	85.6	81.4
3	2.8	19.5	12.9	91.4	61.8
4	32.7	51.1	32.7	0	0

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