MAGNETIC FIELDS AROUND A 220-66 kV TRANSMISSION LINE

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ABSTRACT: The last decade has witnessed growing public concern over possible adverse health effects of magnetic fields produced by generation, transmission and utilization of electric power. Numerous works examined magnetic fields emanating from conventionally designed transmission lines. This paper, in contrast, evaluates magnetic fields around a 220-66 kV, 60 km, transmission line segment specially erected in Egypt. The optimum phase arrangement of the 220 and 66 kV circuits is sought in view of the lowest peak magnetic field value. Furthermore, the mean magnetic field prevailing over a potential exposure area is determined near the line, namely, over an area extending 50 m on both sides of the line span. The effect of line disconnection on magnetic field is investigated. Being vital to human exposure assessment the variation of magnetic field underneath the line along a human height is presented and discussed.

I. INTRODUCTION

The potential hazard due to exposure to extremely low frequency (ELF) electromagnetic fields emitted by electric power systems and installations have become a major public and environmental concern. During the last few years the interest has shifted from electric to magnetic fields where the latter are now generally believed to represent more potential hazard to living organisms [1,2]. To obtain accurate information on the possible biological effects of electric power systems and installations, many analytical and experimental studies have been initiated in recent years. Computational efforts were employed to evaluate magnetic fields in the vicinity of different power line configurations, in substations, in homes and in work places. To predict accurately the magnitudes of magnetic fields, many investigators carried out measured programs in the vicinity of power lines, in occupational environments and in homes [3-5].

This work contributes to the knowledge on magnetic fields by investigating a 220-66 kV common-tower ,60 km, power line segment erected from Nwibaa to Dahab in Sinai Peninsula . The 220 kV line is a double circuit with AAAC conductor bundles of 2x22.7 mm and 30 cm bundle spacing. The 66 kV line is a double circuit with AAAC conductor of 22.7 mm in diameter. The maximum line sag and the span length are 11.5 m and 360m, respectively, as specified by Egyptian Electricity Authority. Fig.1 shows the compound tower with its associated dimensions.

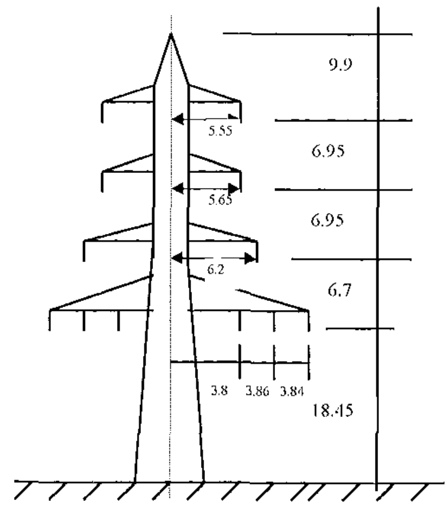

Fig1. 220-66 kV tower configuration dimensions in meters

II. BASE CASE

A three-dimensional magnetic field computation technique is used in the present work. It is based on a model in which the line conductors are simulated by connected straight-line current segments [6]. Magnetic fields are calculated assuming that the two circuits are at full load, i.e. with 1200 A line currents for 220 kV line and 600 A for 66 kV line. The relative permeability is unity everywhere for both air and ground. The magnetic fields are calculated at one meter above ground level unless otherwise mentioned. The base-base phase arrangement of the line is taken as abc/abc from top to bottom for 220 kV circuit and abc-cba, i.e. symmetric, for 66 kV line.

Fig.2 shows the lateral distribution of magnetic field of the base case arrangement at mid-span. The rate of decay of the magnetic field values is very high in the area between the outermost conductor of the 220 kV line and the outermost conductor of the 66 kV line. The rate of decay becomes significantly less beyond the outermost conductor of the 66 kV line. The maximum field values occur under the outermost conductors of the 220 kV line where high cancellation effect is expected at the center line.

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III. EFFECT OF CIRCUIT DISCONNECTION

The effect which circuit disconnection has on magnetic field beneath the line is examined. All possible combinations of circuit disconnection of the base case are investigated. The effect of complete disconnection of the 66 kV line on magnetic field is shown in Fig.3, where magnetic fields decrease in the area immediately underneath the line. Beyond the outermost conductor of the 66 kV line the field is approximately unchanged. This means that the magnetic fields emanating from the 220 kV line is dominant in areas far from the line.

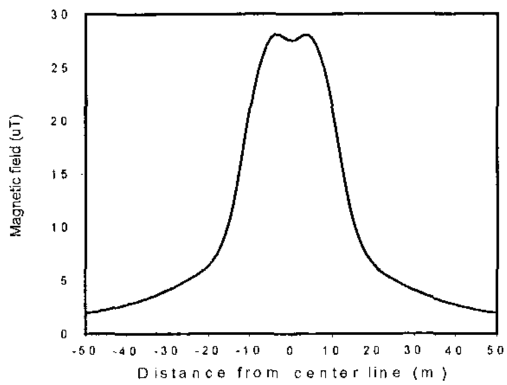

Fig.2 Magnetic field distribution of base line

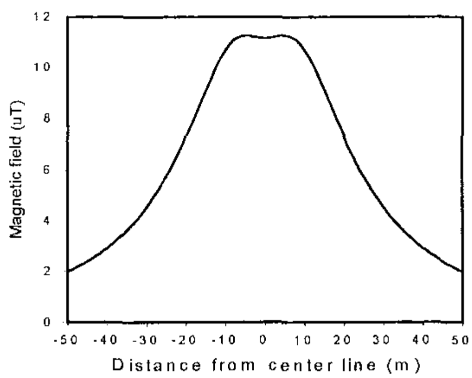

Fig.3 Effect of 220 kV line disconnection

Fig.4 shows the effect of disconnection of the 220 kV circuit. It is seen that rate of decay of magnetic field in the presence of the 66 kV line only is greater than that of the 220 kV line alone, causing the magnetic field at points far from the line to be relatively smaller.

The effect of disconnection of only one of the four circuits is shown in Figs. 5 and 6. Fig.5 shows the effect of disconnection of the left-hand side 220 kV circuit. The magnetic field in the area under the line decreases. The peak magnetic field on the far side of the disconnected circuit is slightly deceased. The effect of disconnection of the left-hand side 66 kV circuit is shown in Fig.6. The magnetic field underneath the disconnected circuit is greatly reduced. Only one peak -under the outermost conductor of the 220 kV circuit- develops on the far side. The magnetic field in the area under the line decreases, while that far from the line is only slightly affected.

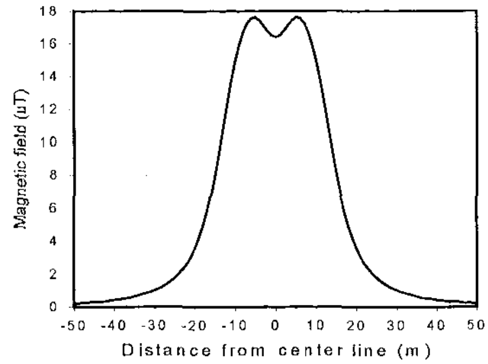

Fig.4 Effect of 66 kV line disconnection

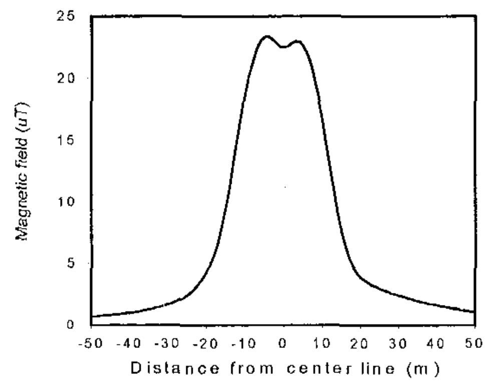

Fig.5 Disconnection of one circuit of 220 kV line

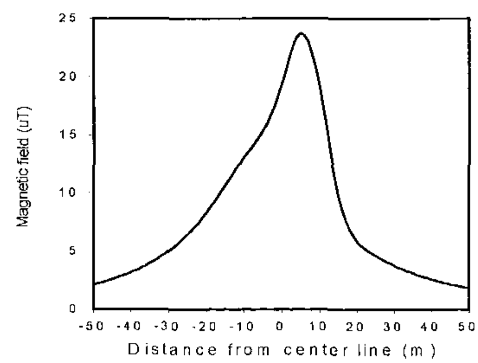

Fig.6 Disconnection of one circuit of 66 kV line

IV. EFFECT OF PHASE ARRANGEMENT

A large number of phase arrangement combinations of the 220 kV circuit and 66 kV circuit are theoretically possible. Specifically, 36 different phase arrangements are possible for each of the 220 kV and the 66 kV lines, resulting in an extremely large number of combinations. Redundancy can be avoided if arrangements that bear the same effect are eliminated thus reducing the phase arrangements of the 220 kV lines to only six "unique" arrangements. Those six arrangements for the 220 kV line are shown in Table 1 as they interact with the 36 phase arrangement of the 66 kV line.

Table 1 Phase arrangements of 200 kV &66 kV lines

Phase arrangement (220 kV)

I	II	III	IV	V	VI
a a	a b	a c	a a	a b	a c
b b	b c	b a	b c	b a	b b
c c	c a	c b	c b	c c	c a

Phase arrangement (66 kV)

1	a b c a b c	19	a c b a c b
2	a b c b c a	20	a c b c b a
3	a b c c a b	21	a c b b a c
4	a b c a c b	22	a c b a b c
5	a b c b a c	23	a c b c a b
6	a b c c b a	24	a c b b c a
7	b c a b c a	25	b a c b a c
8	b c a c a b	26	b a c a c b
9	bc a a b c	27	b a c c b a
10	b c a b a c	28	b a c b c a
11	b c a c b a	29	b a c a b c
12	b c a a c b	30	b a c c a b
13	c a b c a b	31	c b a c b a
14	c a b a b c	32	c b a b a c
15	c a b b c a	33	c b a a c b
16	c a b c b a	34	c b a c a b
17	c a b a c b	35	c b a b c a
18	c a b b a c	36	c b a a b c

All shown phase arrangements combinations are examined, where the magnetic field distribution was produced for each case. Table 2 shows those phase arrangements which gave the least magnetic field sorted by the corresponding peak magnetic field. In the first column the roman number indicates the 220 kV phase arrangement while the neighboring number indicates the 66 kV phase arrangement as given in Table 1. The table also gives the lateral location of the peak magnetic field and field value at the conventional right-of-way of the 220 kV line, i.e. 25m from center line, and also at double that distance. It is seen that the "optimum" phase arrangement, i.e. that giving the least magnetic field, is abc/cba for 220 kV line combined with the phase arrangement abc/abc for 66 kV line.

As an indication of the level of exposure of a human present in the general vicinity of a power line the "mean" magnetic field over the entire exposure area is sought. This area is defined as that bounded by straight lines at 50m from the center line on both sides of the power line and extending over one whole line span. Field values at 1 m above ground within that area were determined and averaged out for a number of phase arrangement. Table 2 shows that larger peak fields do not necessarily produce larger mean exposure fields. However, it is interesting to note that the phase arrangement VI1 which gives the lowest maximum magnetic also gives the lowest mean exposure magnetic field value.

Table 2 Optimum phase arrangements

Phase arrang.	Bmax (μT)	X (m)	B at 50m (μT)	B at 25m (μT)	Mean (μT)
VI 1	10.67	-4	0.38	1.14	1.98
V 14	13.66	12	1.84	6.17	4.61
II 1	13.82	-4	1.24	3.99	3.39
III 25	13.82	4	1.24	3.99	3.39
IV 25	13.86	-3	1.77	5.15	4.81
VI 4	14.03	8	0.53	2.39	2.90
VI 29	14.03	-8	0.53	2.39	2.90
II 22	14.21	-8	1.11	3.78	3.36
III 29	14.21	8	1.11	3.78	3.36
V 18	14.54	11	1.85	6.30	5.06
V 36	14.54	-11	1.85	6.30	5.06
VI 19	14.65	-7	0.74	3.08	3.44
VI 25	14.65	7	0.74	3.08	3.44
I 36	14.78	11	2.08	6.79	5.13
II 19	14.86	-9	1.26	4.38	3.86
III 1	14.86	9	1.26	4.38	3.86
V 32	15.12	11	1.90	6.51	5.29

In contrast, Table 3 shows the "worst" phase arrangements, i.e. those giving the largest peak fields sorted by peak field. It is seen that the absolute worst phase arrangement is abc/abc for 220 kV line combined with phase arrangement abc/cba for 66 kV line. It is interesting to note that case was considered earlier in the paper to be the "base case". It is also indicated that the worst cases have a higher rate of decay of magnetic field beyond the outermost conductor of the 220 kV circuit. The "best" phase arrangement of Table 2 is seen to result in a reduction of peak magnetic field of about 64% compared to that of the "worst" case. This fact reflects the relevance of phase arrangement and the need for such factor to be considered in designing power lines.

Table 3 indicates that the "worst" phase arrangement (I6) also gives the largest mean exposure magnetic field.

V. HUMAN EXPOSURE TO MAGMETIC FIELD

Exposing a human to power-frequency magnetic field induces electro-motive forces within the human body which drives circulating currents in organs and tissues where the current magnitudes are primarily determined by the prevailing conductance. The induced emf ,and in turn the currents, at a given spot within the body is proportional to the magnetic field intensity at that spot. Therefore, it is relevant to examine the distribution of magnetic field along the human body. Since the permeabilities of human bodies and free space are equal a human body is "transparent" to magnetic fields. This ,in turn, means that the distribution of field along the body is not changed by the absence of the body, i.e. in the space where the body is to be present. Consequently, the variation of magnetic field along a virtual erect human in space was examined.

Table 3 Worst phase arrangements

Phase arrang.	Bmax (μT)	X (m)	B at 50m (μT)	B at 25m (μT)	Mean (μT)
I 6	28.05	4	1.92	5.06	7.31
I 27	26.91	4	2.08	6.11	7.16
I 3	26.91	-4	2.08	6.11	7.16
V 30	26.84	3	1.73	5.06	6.87
V 6	26.84	-3	1.73	5.06	6.87
IV 24	26.78	-5	1.65	4.49	6.61
IV 6	26.78	5	1.65	4.49	6.61
V 3	26.34	-3	1.71	4.75	6.67
IV 20	26.34	6	1.72	4.91	7.11
V 27	25.98	-3	1.78	5.32	7.00
I 30	25.94	3	1.98	5.71	7.08
I 20	25.37	5	2.03	5.91	7.14
I 2	25.37	-5	2.03	5.91	7.14
IV 27	25.19	5	1.84	5.44	6.11
IV 21	25.19	-5	1.84	5.44	6.11
III 24	24.88	-5	1.07	3.52	5.57

The variation of the magnetic field values along a human height moving in lateral direction at mid-span for the base case (which is also the "worst" case) and the case of "optimum" phase arrangement are shown in Figs.7 and 8, respectively. The relative increase of magnetic field under the line along the human height of the optimum phase arrangement is more significant than that of the base case.

VI. CONCLUSIONS

The following conclusions are pertinent to the case of two power lines 220 and 66 kV carried by a common tower:

1. Complete disconnection of either the 220 kV line or the 66 kV line results in reducing the magnetic field values under the line while the distribution becomes symmetric around the center line.
2. Disconnection of only one circuit causes a distortion of magnetic field distribution which is particularly obvious in the case of the 66 kv line.
3. The phase arrangement abc/cba of 220 kV line combined with abc/abc phase arrangement for 66 kV line gives the all-out lowest field which is 64% lower than the case with maximum field.
4. The optimum phase arrangement gives also the lowest mean exposure value underneath the line.
5. The increase of magnetic field under the line along a human height in case of the optimum phase arrangement is relatively quite significant.

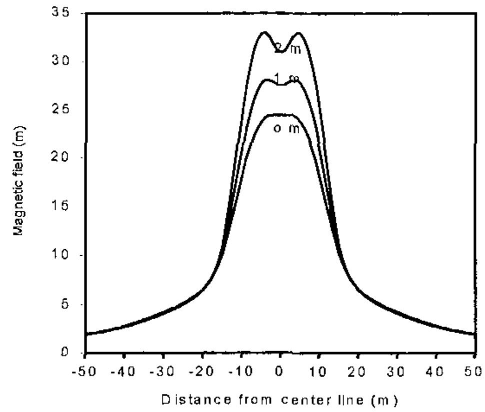

Fig.7 Effect of height above ground of base line

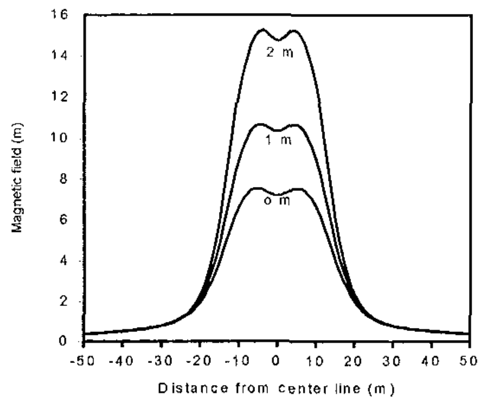

Fig.8 Effect of height above ground of optimum phase arrangement line

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