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Magnetic field distributions under crossing power lines

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Abstract: As a contribution to the assessment of expected biological risk from exposure to power line magnetic fields, this paper addresses the issue of magnetic field distributions under crossing power lines. Cases of crossing 500 & 66 kV lines and crossing 220 & 66 kV lines are studied. For such cases, the magnetic field profiles for different crossing angles are developed and analyzed. The magnetic field contours in the area surrounding the crossing lines are also developed. On the other hand, the effects of phase arrangement and current direction on the magnetic field levels and distributions under the crossing lines are evaluated.

1. Introduction

The interaction between the power frequency (50/60 Hz) magnetic fields and the living organisms still draw worldwide attention because of the results of a number of studies which indicated possible harmful effects due to the exposure to these fields. In parallel to the laboratory and the epidemiological studies many researches addressed the evaluation of the magnetically-induced currents in living organisms [1-2].

Many studies have been carried out to evaluate the magnetic fields beneath different power lines which are considered as major sources of induction [3-5]. However, these lines are dealt with individually, i.e. magnetic fields are evaluated under single power lines. Two recent studies were published which investigated the magnetic field distributions under parallel transmission lines [6-7]. The results showed that the magnetic field profiles under parallel lines were apparently different when compared to those under single lines.

Many cases of power lines crossing can be found. If a power line is constructed under another line and crossed it, the angle between their line centers is called “crossing angle”. The crossing angle of the lines varies from a case to another. On the other hand, the higher voltage line is suspended above the lower voltage line while respecting a vertical distance called “permissible minimum vertical clearance for crossing lines”. This distance is determined according to the standards and varies according to the level of the higher voltage line.

To expand the thorough investigation to other cases of power lines neighborhood, this paper investigates the magnetic field distribution under crossing power lines using a three-dimensional magnetic field computational technique [8]. Typical 500, 220 and 66 kV power line configurations in Egypt are used for the current study. The magnetic field distributions under crossing 500 & 66 kV lines and crossing 220 & 66 kV lines are studied. The longitudinal magnetic field profiles for different crossing angles are developed and analyzed. Also, the magnetic field contours in the area surrounding the crossing lines are developed and the statistical analysis of the prevailing magnetic field is carried out. On the other hand, the effects of phase arrangement and current direction on the magnetic field levels and distributions under the crossing lines are evaluated.

2. Employed Power Line Conductor Configurations

Figures 1a, 1b and 1c present the line conductor configurations and dimensions of the employed 500, 220 and 66 kV lines, respectively. The 500 kV line is with a single circuit tower, a line span of 400 m, three subconductors per phase, a spacing between subconductors of 45 cm and a minimum clearance-to-ground of 9 m. The 220 kV line is with a double circuit tower, a line span of 360 m, two subconductors per phase, a spacing between subconductors of 30 cm and a minimum clearance–to-ground of 7 m. The 66 kV line is with a double circuit tower, a line span of 250 m, one conductor per phase and a minimum clearance-to-ground of 6 m.

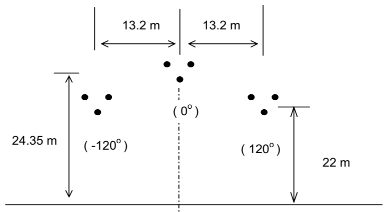

Figure 1a: Line conductor configuration of 500 kV line

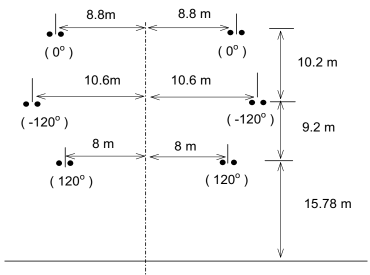

Figure 1b: Line conductor configuration of 220 kV line

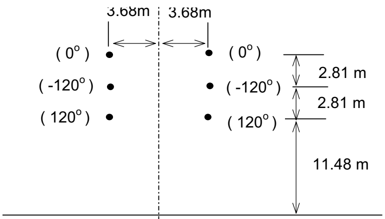

Figure 1c: Line conductor configuration of 66 kV line

3. Crossing 500 and 66 kV Lines

Simulation of crossing 500 and 66 kV lines

A 66 kV line is assumed to cross a 500 kV line. The two lines have the same configurations of Figures 1a and 1c. For simplicity, it is considered that the center of crossing is at mid spans of the crossing lines. For any line crossing the 500 kV line, the permissible minimum vertical clearance between the two lines is 7 m, according to the Egyptian standards. In the simulation, the 500 kV line conductors of the crossing span (span 2) are raised by 9.52 m to achieve the permissible minimum vertical clearance.

Figure 2 shows the horizontal projection of the crossing 500 and 66 kV lines for different crossing angles (90°, 60°, 45° and 30°). It is noticed that the center of crossing occurs at mid span 2 of the 500 kV line and mid span 4 of the 66 kV line.

Longitudinal profiles of magnetic fields

Figure 3 shows the longitudinal magnetic field profiles beneath the centerline of 500 kV line for crossing 500 and 66 kV lines at different crossing angles. It is noticed that the case of crossing angle 90° produces the maximum value of the magnetic field (20.3 µT) which occurs at 6 m before the center of crossing as well as the minimum value (3.2 µT) which occurs at 9 m beyond the center of crossing. As the crossing angle decreases, the location of maximum or minimum magnetic field is shifted away from the center of crossing and their values decrease as well. It is also noticed that the disconnection of 66 kV line (i.e. the operation of 500 kV line only) reduces the maximum magnetic field value to 9.9 µT while the minimum magnetic field value reached 5.4 µT.

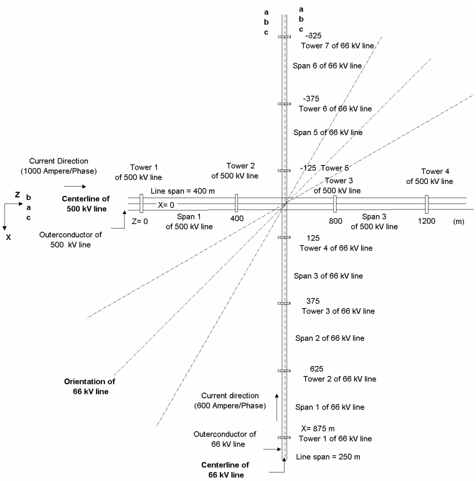

Figure 2: Horizontal projection of crossing 500 and 66 kV lines

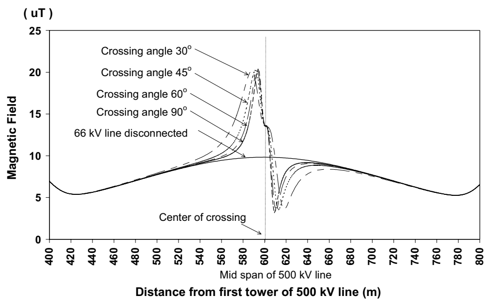

Figure 3: Longitudinal magnetic field profiles beneath centerline of 500 kV line for crossing 500 and 66 kV lines

Equi-magnetic field contours

Figure 4 shows the equi-magnetic field contours in the zone occupying crossing spans of crossing 500 and 66 kV lines in the case of crossing angle 90°. It is noticed that the magnetic field contours are symmetric around the centerline of 500 kV line. On the other hand, the zones of higher magnetic field values concentrate around the center of crossing. The magnetic field contours outside the outermost conductors follow the centerlines of the crossing lines.

In the case of crossing angle 45°, the zones which are characterized by the presence of higher magnetic field values are wider than those related to the case of crossing angle 90°.

Effect of phase arrangement

Unlike the above sections which considered the normal phase arrangement (abc) / (abc, abc), the effect

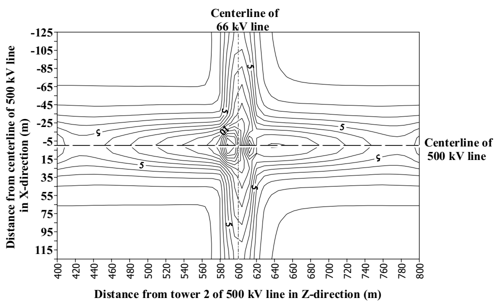

Figure 4: Equi-magnetic field contours (uT) in the zone occupying crossing spans of crossing 500 and 66 kV lines for crossing angle 90 degree

of phase arrangement on the magnetic field levels and distributions under the crossing 500 and 66 kV lines is taken into account. The 500 kV line is estimated to have a normal phase arrangement (abc) while the 66 kV line is estimated to have a varying phase arrangement. Three different phase arrangements for the 66 kV line are, thus, considered; (abc, *abc*), (abc, *bca*) and (abc, *cab*).

For the phase arrangement (abc) / (abc, *bca*), Figure 5 shows the longitudinal magnetic field profiles beneath the centerline of 500 kV line for crossing 500 and 66 kV lines at different crossing angles. It is noticed that the case of crossing angle 90^{o} produces the maximum value of the magnetic field (16.8 μT) which occurs at 6 m before the center of crossing. On the other hand, the minimum value of magnetic field (5 μT) is reached at 1 m beyond the center of crossing in case of crossing angle 30^{o}.

In comparison, the normal phase arrangement (abc/abc, *abc*) produces the highest magnetic field values among all studied cases of phase arrangement. While the other phase arrangements; (abc/abc, bca) and (abc/abc, cab) produces lower magnetic field values at locations far from the line.

4. Crossing 220 and 66 kV Lines

Simulation of crossing 220 and 66 kV lines

In this case, a 66 kV line is assumed to cross a 220 kV line. The two lines have the same configurations of figures 1b and 1c. For simplicity, it is considered that the center of crossing is at mid spans of the crossing lines. For any line crossing the 220 kV line, the permissible minimum vertical clearance between the two lines is 5 m, according to the Egyptian standards. In the simulation, the 220 kV line conductors of the crossing span (span 2) are raised by 9.52 m to achieve the permissible minimum vertical clearance.

Longitudinal profiles of magnetic fields

Figure 6 shows the longitudinal magnetic field profiles beneath the centerline of 220 kV line for crossing 220 and 66 kV lines at different crossing angles. It is noticed that the case of crossing angle 30^{o} produces the maximum value of the magnetic field (21 μT) which occurs at 7 m before the center of crossing and the minimum value (7.5 μT) which occurs at 152 m beyond the center of crossing. As the crossing angle decreases, the maximum value of magnetic field increases and its location is shifted away from the center of crossing while the magnetic field value at center of crossing increases. The magnetic field profile is symmetric around the center of crossing in all cases. It is also noticed that the disconnection of 66 kV line (i.e. the operation of 220 kV line only) reduces the maximum magnetic field value to 10.2 μT while the minimum magnetic field value reached 7.5 μT.

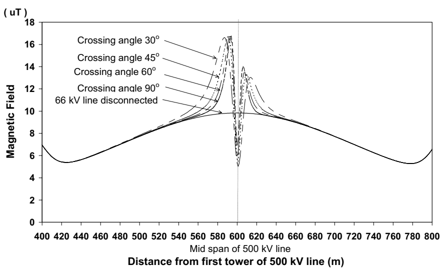

Figure 5: Longitudinal magnetic field profiles beneath centerline of 500 kV line for crossing 500 and 66 kV lines (Phase arrangement abc/abc, bca)

Equi-magnetic field contours

Figure 7 shows the equi-magnetic field contours in the zone occupying crossing spans of crossing 220 and 66 kV lines in cases of crossing angle 45^{o}. It is noticed that the zones of higher magnetic field values concentrate around the center of crossing. The magnetic field contours showed inverted symmetry around centerlines.

When compared to the case of crossing angle 90^{o}, the zones which are characterized by the presence of higher magnetic field values are wider and the values of the magnetic field are higher.

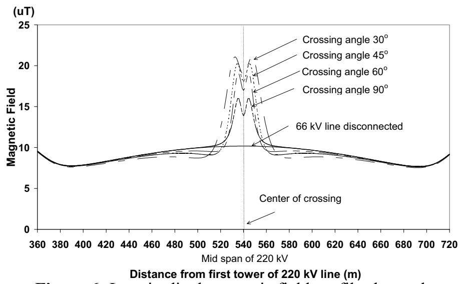

Figure 6: Longitudinal magnetic field profiles beneath centerline of 220 kV line for crossing 220 and 66 kV lines

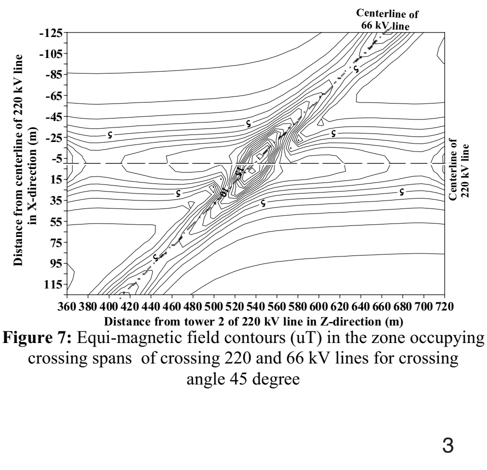

Figure 7: Equi-magnetic field contours (uT) in the zone occupying crossing spans of crossing 220 and 66 kV lines for crossing angle 45 degree

Effect of current direction

The effect of current direction on the magnetic field levels and distributions under the crossing 220 and 66 kV lines is considered where the load (or current) in the 66 kV line is estimated to flow in an opposite direction. Figure 8 shows the longitudinal magnetic field profiles beneath the centerline of 220 kV line for crossing 220 and 66 kV lines at different crossing angles in the case of opposite current direction. It is noticed that the maximum value of the magnetic field is 16 μT and occurs at 4 m before the center of crossing in case of crossing angle 90° while the minimum value is 5.4 μT and occurs at the center of crossing in case of crossing angle 30°. The magnetic field profile is symmetric around the center of crossing in all cases.

5. Conclusion

1. For crossing lines, the zone of higher magnetic field values concentrates around the center of crossing. The area of this zone is increased by decreasing the crossing angle.
2. In the case of crossing 500 & 66 kV lines, all the crossing angles except 90° produce magnetic field contours which are non-symmetric around the center of crossing. While in the case of crossing 220 & 66 kV lines, all the crossing angles produce magnetic field contours which are invertedly symmetric around the center of crossing.
3. In the case of crossing 220 & 66 kV lines, as the crossing angle increases, the maximum value of the magnetic field decreases. While in the case of crossing 500 & 66 kV lines, as the crossing angle increases, the maximum value of the magnetic field increases as well.
4. The normal phase arrangement in the case of crossing 500 & 66 kV lines produces the highest magnetic field values among all the studied cases of phase arrangements.
5. For crossing 220 & 66 kV lines, the flow of load in an opposite direction in the 66 kV line would result in reducing the maximum magnetic field values for all cases of crossing angles except the case of crossing angle 90° where no change occurs. On the contrary, higher magnetic field values at far locations are produced.

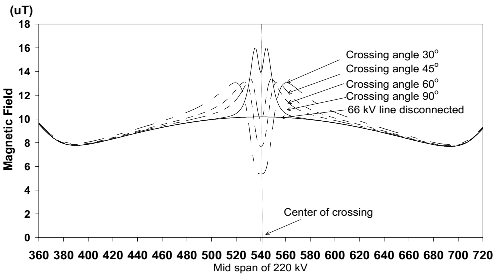

Figure 8: Longitudinal magnetic field profiles beneath centerline of 220 kV line for crossing 220 and 66 kV lines (66 kV line with opposite current direction)

6. References

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