International Conference on Electronics, Computer and Communication (ICECC 2008)
University of Rajshahi, Bangladesh

Electromagnetic field effect of high-voltage ac transmission line: A case study

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ABSTRACT
As the time varying current flows in the conductor of high-voltage transmission line, there exists electric and magnetic field around the conductor. This paper investigates the magnetic field around the conductor and calculates the magnetic field at 2m height from the ground and checks whether it is safe for humans or other objects in the vicinity. The author defined the surface current densities at the boundary of the conductor and magnetic insulation at all boundaries of the Gaussian surface. A test case had been considered for this investigation. Comsol Multiphysics® had been used for equation set up for solving the problem and simulation.

Key Words: Electromagnetic field, High-voltage transmission line.

1. INTRODUCTION

A typical high-voltage line has three phase conductors to carry the current and transport the energy from generation stations to consumers, and two grounded shield conductors to protect the line from direct lightning strikes. Usually bare conductors are insulated from the supporting towers by insulators attached to grounded towers or poles. These high voltage lines produce electric and magnetic field around their vicinity, which are likely to have harmful effects on plants, animals and human beings when their level are beyond certain limits. Long term health effects from electric and magnetic fields were also studied by many scientists and suggested that the long term exposure to these fields are potentially harmful and should be minimized [1]. For general public as per IRPA (International Radiation Protection Association) guidelines the safe limits for electric field and magnetic field for general public exposure and occupational exposure of the magnetic field for different places is specified as [2]:

Exposure to the general public:

50 Hz: 100microT and 5 kV/m
60 Hz: 84 micro T and 4.2 kV/m

Occupational exposure:

50 Hz: 500 -1000microT and 10 kV/m
60 Hz: 417 microT and 8.33 kV/m

This work had been carried out by the author with Chalmers University of Technology, Department of Electric Power Engineering, Göteborg, Sweden, during one of the M.Sc. Engineering course projects.

But there is great controversy over the result obtained by the researchers. The matter of controversy is that whether the magnetic field and electric field for power frequency causes child leukemia and cancer or not.

2.PROBLEM STATEMENT & FORMULATION

Line data : 100 MVA, 400 kV overhead ac transmission line.
Conductor type : Bundle conductor, triplex type, dia 0.04m, placed at vertices of an equilateral triangle of side 0.45m.
Phase arrangement : Vertically hanging, phase to phase clearance= 9m, Ground clearance=8m.

Problem setup was done in Comsol Multiphysics® as Magnetostatics (2D) to solve the following equation:

$$\nabla \times \left(\mu_0^{-1} \mu_r^{-1} \nabla \times A_z\right) - \sigma v \times \left(\nabla \times A_z\right) = \sigma \Delta V / L + J^e{}_z$$

The constitutive relation was set as $B = \mu_0 \mu_r H$ (with $\mu_r = 1,$ *isotropic*)

Surface current densities with different ωt had been considered. Static analysis had been done using parametric linear solver settings.

3. SIMULATION RESULTS

Variation of magnetic field around the conductor at different time instant depicted in the following figures (Fig.1 to Fig.3):

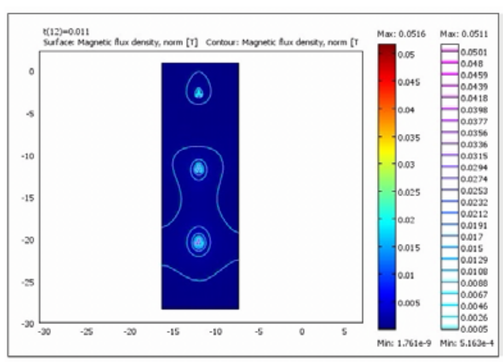

Fig.1: Variation of magnetic flux density (t=0.011)

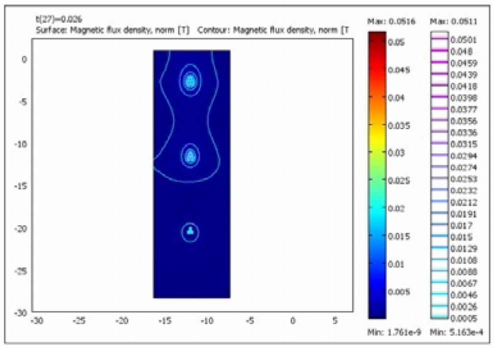

Fig.2: Variation of magnetic flux density (t=0.026)

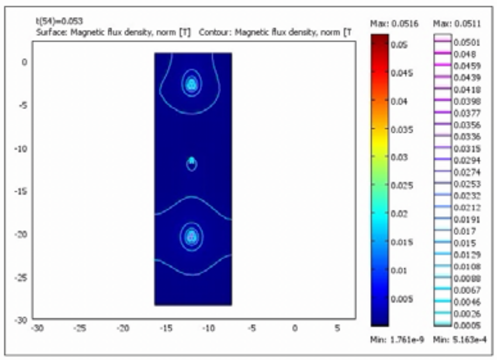

Fig.3: Variation of magnetic flux density (t=0.053)

The following simulation result (Fig.4) shows the distribution of magnetic field strength at different heights at different time instants in vertical direction, which tells us that as we go on near to power conductor in vertical direction, the magnetic field strength becomes higher.

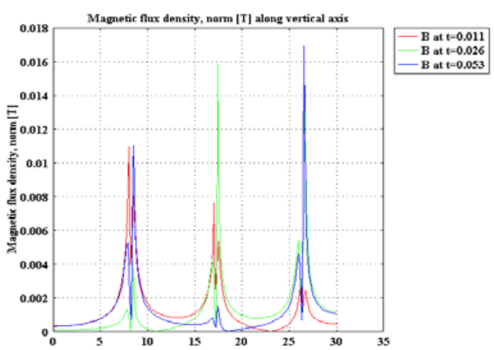

Fig.4: Distribution of magnetic flux density along vertical axis

The following simulation results show the magnetic field strength at t =0.1 seconds at different heights from the ground (Fig.5 and Fig.6). As we seen in the graph, the magnetic field strength is higher as we go near to power conductor towards vertical or horizontal direction.

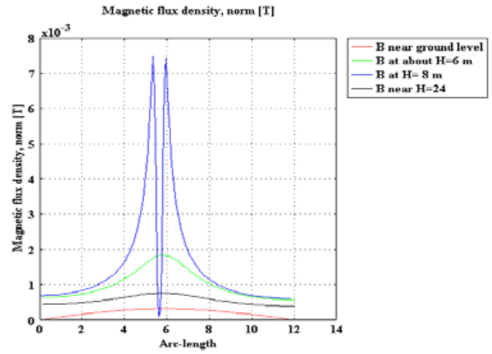

Fig.5: Magnetic flux densities at ground level and 6m, 8m, 24m above ground level

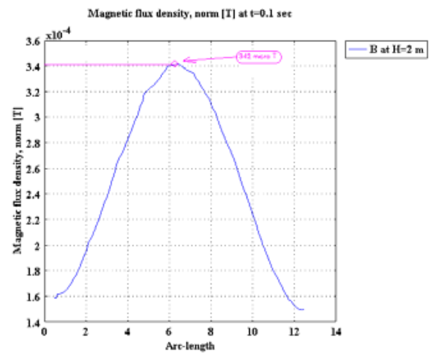

Fig.6: Magnetic flux density at 2m above ground level

The magnetic field at 2 m height above under the power conductor is found to be 342 micro Tesla and it is 178 micro Tesla at a distance 4.85 m away from the power conductor in horizontal direction.

3. CONCLUSIONS

The magnetic field just below the power conductor at 2m height is found to be 342micro Tesla and go on decreasing as we move away from the tower. The magnetic field strength at 2 m height under power conductor is less than the exposure limit specified for the occupational personnel who works in power station, high voltage transmission substation and its vicinity. Results shown, the magnetic field strength at 2 m height at 4.85m away from power conductor along horizontal direction is 178 micro Tesla.The distribution of the magnetic field is reduced by inverse square law as we go away from the power conductor i.e. if distance is doubled, and then the magnetic field strength reduces to one fourth. So the magnetic field at a distance 10 m away from conductor is about 37 micro Tesla which is below the 100 micro Tesla limit specified for general public. Since the transmission line corridor for 400kV is more than several of meters, the magnetic field obtained at 2 m height under power conductor is within safe limit as specified by the International Radiation Protection Association (IRPA).

3. ACKNOWLEDGEMENTS

The author acknowledges the financial support to conduct the Masters in Electric Power Engineering at Chalmers University of Technology, Göteborg, Sweden provided by Swedish Institute (SI).

Also acknowledges sincere gratitude to Prof.Yuri Serdik for his support during this project work and to Madhab Paudel as project mate.

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[2] International Radiation Protection Association/INIRC guide lines, Health Physics, Jan 1990 Vol.58.