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Evaluation Of Electromagnetic Environmental Impact Of Different Transmission Line Configurations Used In Pakistan

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Abstract: Electric Power transmission lines are the bulk power carriers which are characterized by high voltages and currents. These parameters create an electromagnetic environment in the proximity of transmission lines. The combined effects of which can be sensed in the near vicinity and even at ground level. The electric and magnetic field values are needed as part of Environmental Impact Assessment (EIA) report for the transmission lines and in selecting the ROW (Right of Way) for the transmission line projects. This paper presents the analytical results of the calculation of magnetic field and electric field generated by transmission lines and different geometrical tower configurations of WAPDA (Water and Power Development Authority) Pakistan. Calculation of these values is emphasized from environmental and health point of view. Some of the leading studies on this issue and their conclusions are discussed. The limiting values as applicable to right-of-way of transmission lines are discussed according to the guidelines of International Commission on Non-Ionizing Radiation Protection (ICNIRP).

Keywords: *Electromagnetic Field, Health Effects, Transmission line, Magnetic Field Reduction*

I. INTRODUCTION

Electric Power transmission lines are ubiquitous part of electric power system that carries bulk power from distant generating stations to load centers. They are operated at high voltages and high currents depending upon the standard that particular country follows. These high voltages and currents create an electromagnetic environment in the vicinity of the transmission line. These fields can affect the human beings and nearby objects in the proximity of transmission lines. Hence as part of any transmission line project it is necessary to conduct EIA (Environmental Impact Assessment) and accordingly plan the ROW (Right Of Way) for the transmission line projects. As part of EIA report, one of the main studies relates to Field mapping (electric and magnetic) in the surrounding region of the transmission lines. In this paper the field mapping has been done for the common geometrical configurations of towers used in the network of WAPDA Pakistan.

II. ELECTRIC & MAGNETIC FIELD EXPOSURE

Electric field is associated with the voltage and magnetic field with the flow of current. These fields have the tendency to induce currents in human body and nearby objects. The induced current in the body depends upon many factors such as line current, distance from the source, tissue conductivity in the body and also on body shape, orientation and posture [1-3]. Many Studies have been conducted in order to see whether the induced currents in human body have the tendency to disrupt the normal functioning of body. Since 1970's more than 20 epidemiological studies have been carried out but all produced varying results, some of the experiments showed an elevated risk factor while others produced a negative result [3]. Major studies have been reported and summarized in [4] including the study by NCR (National Research Council), National Academy of Sciences and some other institutes. All these studies were consistent in proving that it is very unlikely or uncertain that electric and magnetic fields from power transmission lines can induce leukemia or other health effects. Under this scientific uncertainty WHO (World Health Organizations) and other international organizations have established the exposure limits that must be observed while planning any new Electrical facility. Currently there is tremendous increase in the urban power load and it necessitates that transmission lines be passed through the urban environment. Hence the power frequency electric and magnetic fields have become the focus of Electromagnetic compatibility technology [5] and for every new transmission line project EIA is compulsory. Every country sets its own standards related to exposure limits of EMF as shown in [6] but they usually draw guidelines from International Commission on Non-Ionizing Radiation Protection (ICNIRP) [7]. The international standards exposure limits as defined in (ICNIRP) for human beings both for general public and occupational persons are given in table 1 and 2 [8]. These values are reference levels for general public and occupational persons given as unperturbed RMS values for time varying electric and magnetic fields

Table 1: General Public Reference Levels

range	Electric field strength –E (KV/m)	Magnetic field strength –H (A/m)	Magnetic field density-B (T)
I Hz – 8Hz	5	$3.2 * 10^4/f^2$	$4 * 10^{-2}/f^2$
8 Hz – 25Hz	5	$4 * 10^3/f$	$5 * 10^{-3}/f$
25 Hz – 50Hz	5	$1.6 * 10^2$	$2 * 10^{-4}$
50 Hz – 400Hz	$2.5 * 10^2/f$	$1.6 * 10^2$	$2 * 10^{-4}$
400 Hz – 3KHz	$2.5 * 10^2/f$	$6.4 * 10^4/f$	$8 * 10^{-2}/f$
3 KHz – 10MHz	$8.3 * 10^{-2}$	21	$2.7 * 10^{-5}/f$

Table 2: Occupational Reference Levels

Frequency range	Electric field strength –E (KV/m)	Magnetic field strength –H (A/m)	Magnetic field density-B (T)
I Hz – 8Hz	20	$1.63 * 10^5/f^2$	$0.2/f^2$
8 Hz – 25Hz	20	$2 * 10^4/f$	$2.5 * 10^{-2}/f$
25Hz –300Hz	$5 * 10^2/f$	$8 * 10^2$	$1 * 10^{-3}$
300 Hz – 3KHz	$5 * 10^2/f$	$2.4 * 10^5/f$	0.3/f
3 KHz – 10MHz	$1.7 * 10^{-1}$	80	$1 * 10^{-4}/f$

III. WAPDA TRANSMISSION NETWORK

The transmission network of Pakistan is operated and maintained by NTDC (National Transmission & dispatch Company) currently it maintains 5110.48 Km of 500 KV lines and 9686.32 Km of 220 KV lines in Pakistan [9]. The transmission network of Pakistan with existing and modified network is shown in figure 1 [10].

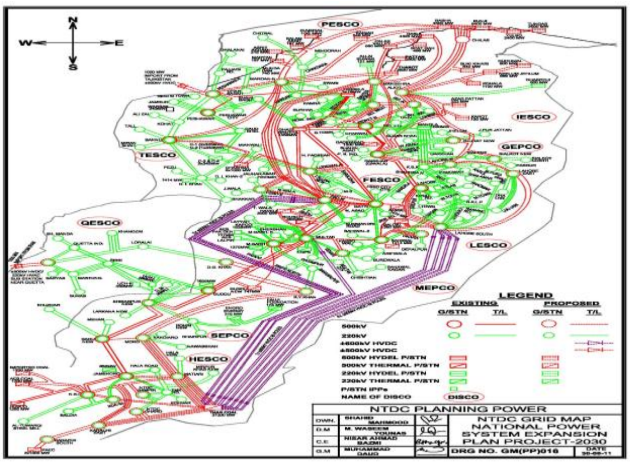

Fig 1: Transmission Map of Pakistan

The common transmission towers used in WAPDA system are shown in figures 2,3 and 4.

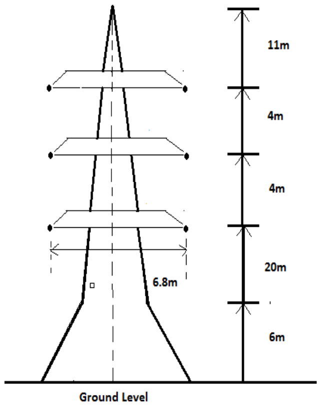

Fig 2: 132 KV Tower Configuration WAPDA

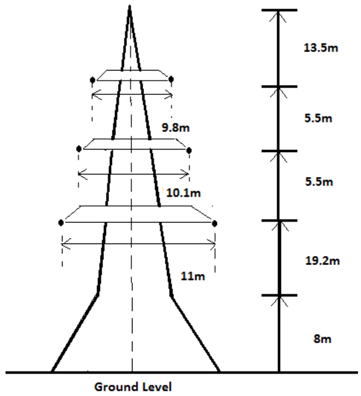

Fig 3: 220 KV Tower Configuration WAPDA

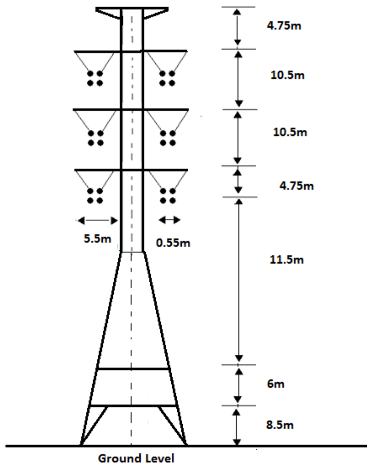

Fig 4: 500 KV Tower Configuration WAPDA

The most common conductors used in WAPDA system are Rail and Merlin Conductors. Below the magnetic and electric field calculations has been done for the above towers under the rated capacity of Rail, Curlew and Merlin conductors.

IV. ELECTRIC AND MAGNETIC FIELD CALCUALTION

Electricity is always associated with the production of magnetic and electric fields in its proximity. Electric field produced depends upon the voltage level, geometrical configuration of conductor, conductor height and lateral distance. Similarly magnetic field produced by power transmission lines depends on phase current, geometrical configuration of conductor, conductor height from ground and lateral distance [11].A MATLAB code was developed for the calculation of magnetic and electric field based on the equation (1) ~ (6) for power lines[12].

$$\overrightarrow{E_A}(x,y) = \frac{-q_A}{A\pi\varepsilon_o}\left[\frac{2(y+y_{oA})u_y+2(x-x_{oA})u_x}{(y+y_{oA})^2+(x-x_{oA})^2} - \frac{2(y-y_{oA})u_y+2(x-x_{oA})u_x}{(y-y_{oA})^2+(x-x_{oA})^2}\right] \quad (1)$$

Here E_A represents the electric field at point (x,y) due to conductor located at (x_{oA}, y_{oA}) and u_x and u_y are the unit vectors in direction x and y. further charge q_A is given by

$$q_A = V_{An} C_A \quad (2)$$

Here

q_A= Charge on phase A

V_{An}= Phase to neutral voltage of conductor A

C_A= Phase to neutral capacitance

C_A can be determined using eq: (3)

$$C_A = \frac{2\pi\varepsilon_o}{\ln\left(\frac{GMD}{r_A}\right)} \quad (3)$$

The capacitance for the WAPDA towers was calculated using the modified GMD (Geometric Mean Distance) method. Similarly the equations for the magnetic field calculation are

$$Bx = \sum_{j=1}^{n} \frac{\mu_{0*} I_{j*} Y_j}{2\pi(x^2+y^2)} \quad (4)$$

$$By = \sum_{j=1}^{n} \frac{\mu_{0*} I_{j*} Y_j}{2\pi(x^2+y^2)} \quad (5)$$

$$B = \sqrt[2]{|B_x|^2 + |B_y|^2} \quad (6)$$

Here μ_o, n and I_j are the permeability, total number of conductors and current in conductor j.

V. MATLAB GRAPHS

The Electric and Magnetic field plots were obtained based on the code developed using the above equations. Below are shown MATLB graphs for the magnetic field for three geometrical configurations of tower and most common conductors used in high voltage systems. The most common conductors used are Rail, Curlew and Martin conductors [13]. The ampacity of these conductors are 993 A, 1047 A and 519 A respectively.

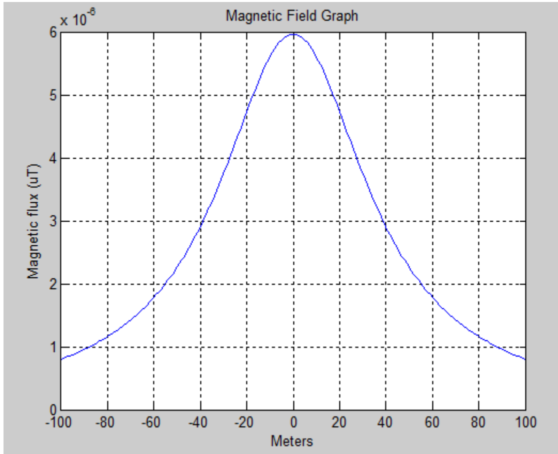

Fig 5: 132 KV Tower Magnetic Field (Rail Conductor)

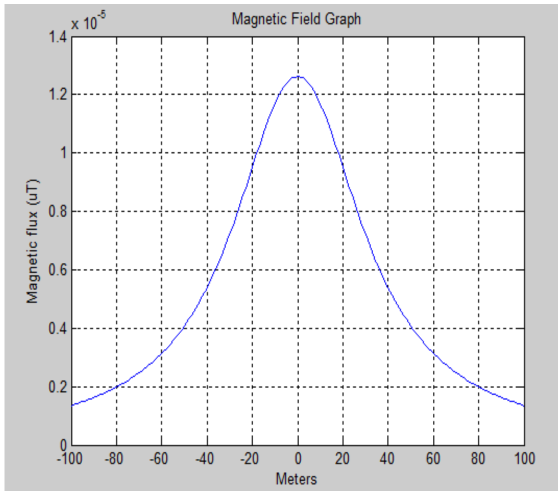

Fig 6: 220 KV Tower Magnetic Field (Curlew Conductor)

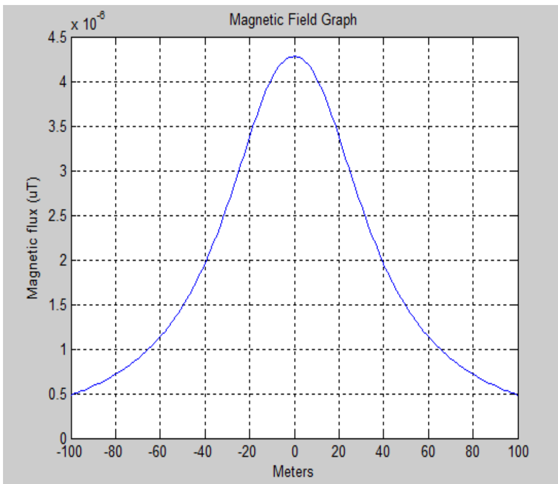

Fig 7: 500 KV Tower Magnetic Field (Merlin Conductor)

As discussed above the conductor with highest ampacity i.e. curlew conductor has the highest magnitude in its ROW followed by Rail conductor and finally the least value is obtained for Merlin Conductor.
The electric field plots for these three tower configurations are shown in figure 8,9 and 10 below

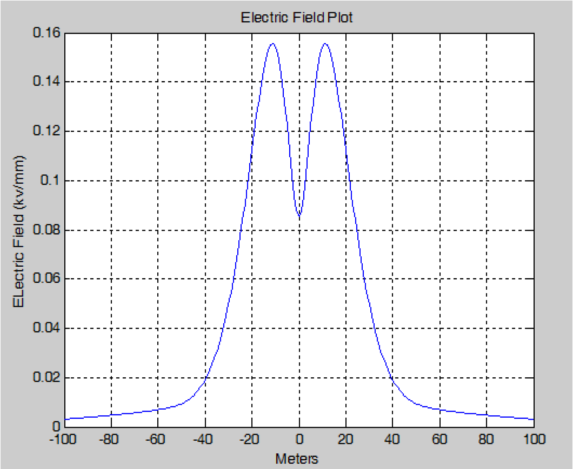

Fig 8: Electric Field Plot 132 KV Tower

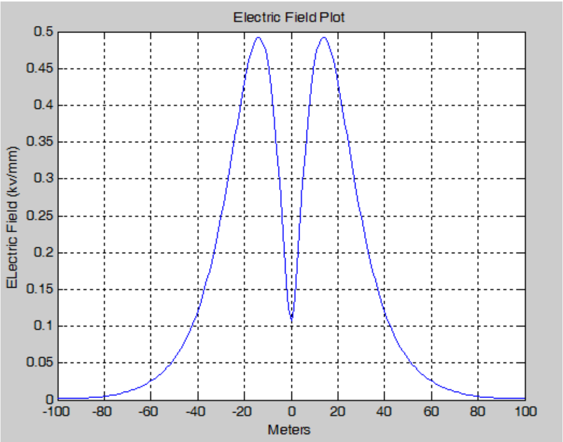

Fig 9: Electric Field Plot 220 KV Tower

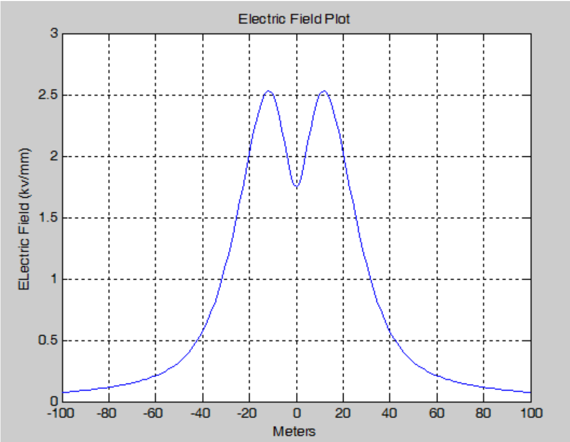

Fig 10: Electric Field Plot 500 KV Tower

Since Electric field is in proportional to voltage hence from electric field plots it can be seen that the highest electric field strength is obtained in the ROW of 500 KV tower followed by 220 KV tower and least value is obtained for 132 KV tower.

VI. METHODS OF REDUCTION

As discussed above it is necessary to keep the EMF exposure within limits hence some of the mitigation methods can be adopted for transmission lines that produce higher magnetic and electric field in the ROW. These mitigation methods are discussed as in [6, 12, 14]. In reference [6], electric and magnetic field for 400 KV transmission lines have been plotted with different heights and geometrical configurations. The increase in height of the tower has the advantage of reducing electric and magnetic fields in the narrow corridor of the transmission but with little effect in values in wider corridor. But by employment of “split phase” configuration there is significant reduction in values for both. Particle Swarm Optimization (PSO) technique can also be employed using different arrangements of conductors and results have shown that the electric and magnetic fields are curtailed by 97%n [12] . In [14], multiple methods for reduction of field has been given such as distancing the electrical facilities form people, using shielding materials and using balanced circuits.

VI. CONCLUSION

In this paper the electric and magnetic fields have been calculated and graphed in the vicinity of the most common tower geometrical configurations used in WAPDA system using MATLAB. The maximum values obtained for magnetic field for three towers is from 4.25 to 12.5 micro tesla and the maximum values obtained for electric field are 0.15 to 2.5 KV/mm. Comparing these values with reference values in table 1 and 2 above shows that these values are below the guideline levels. Furthermore the electric and magnetic fields for any high voltage transmission line can also be reduced especially if it is passing through any populated area. This paper also has the scope for the upcoming projects in Pakistan related to the installation of new and extension of existing transmission lines. Especially the new project named as Transmission Project TP-1000 aims to install new transmission circuits rated at 765 KV as well. Consequently Field Management programs should be started in utilities of Pakistan similar to other utility companies in world such as PPL Electric Utilities Corporation [15].

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