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Electrostatic Field Effect on Human Body due to 400kV Overhead Transmission Line of Different Configurations

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Abstract – *This paper presents the electrostatic field effects from 400kV overhead single circuit horizontal, single circuit triangular and double circuit transmission line configurations. In modern world exposure to electric field is not a new phenomenon and everyone are exposing to various degrees of electromagnetic fields and levels are continuously increasing as technology getting advanced. The aim and objective of this paper is to analyze the electric field on humans placed under high voltage transmission lines using FEMM 4.2 software operates on the principle of finite element method.*

Key Words: Electrostatic field, FEMM, 400kV transmission line.

1. INTRODUCTION

Electromagnetic radiations has been around since the birth of the universe and during 21st century, environmental exposure to artificial electric fields has been steadily increasing because of growing electricity demand, ever advancing technologies and changes in social behavior have created more artificial sources and electric field is a part of spectrum of electromagnetic radiations extends from static electric fields through radio-frequency and infrared radiations to X-rays [1].

Exposure of human beings to electric fields from high voltage transmission lines has been a great concern for humans as it leads to several possible health hazards because transmission lines are found far and wide in our vicinity. In human body, tiny electrical currents exists due to chemical reactions occur as part of normal body function even in the absence of electric fields [1, 2].

High voltage transmission lines emit high levels of electromagnetic radiations and these radiations interact with natural electromagnetic fields exists within human body effecting cell function, breaking DNA strands and eroding the immune system causing short and long term health problems [3].

The effect of electromagnetic radiations emitted from high voltage transmission lines on human health has been studied by many researchers [4, 5, 6].

The present paper investigates the effect of electric field intensity and potential on human body under high voltage transmission lines of different configurations. Electric field in the vicinity of overhead transmission lines depends on voltage of the line, conductor configuration and height of the conductor above the ground. This paper aimed at electric potential and electric field intensity of humans, placed directly under line and comparison is made between different line configurations.

2. NUMERICAL METHODS

Numerical methods are used to determine the field distribution for complex geometries, where it is cumbersome and expensive to use analytical techniques or run laboratory tests. The analysis of a realistically heterogeneous model for humans is a difficult theoretical task. The basis of this analysis are Maxwell's equations. The following are the different methods to solve the Maxwell's equations:

- Charge Simulation Method
- Finite Difference Method
- Boundary Element Method
- Finite Element Method

The Finite element method is most widely used in numerical solution of electric field problems as it is flexible and can be applied to the most complicated geometries and capable of giving accurate results and the accuracy depends on the number of elements considered in the geometry. It is suitable for small domain problems with limited and closed boundary conditions. Finite element method includes accurate electric field calculation, enhanced design and faster response and has the ability to deal with complex 2D domains and more suitable to take boundary conditions into account.

3. MATHEMATICAL FORMULAE OF ELECTROSTATIC FIELD OF A.C LINES

The electric field intensity at a point (x, y) is

$$E = (E^2_{hn} + E^2_{vn})^{1/2}$$

Where,

E_{hn} = Horizontal component of electrostatic field due to n phases = $J_h . V$

E_{vn} = Vertical component of electrostatic field due to n phases = $K_v . V$

V = r.m.s value of line to ground voltage

J_h = $(J^2_{h1} + J^2_{h2} + J^2_{h3} - J_{h1} J_{h2} - J_{h2} J_{h3} - J_{h3} J_{h1})^{1/2}$

$K_v = (K^2_{v1} + K^2_{v2} + K^2_{v3} - K_{v1} K_{v2} - K_{v2} K_{v3} - K_{v3} K_{v1})^{1/2}$

For a single circuit line,

$K_{v1} = K_1 . M_{11} + K_2 .M_{21} + K_3 .M_{31}$

$K_{v2} = K_1 . M_{12} + K_2 .M_{22} + K_3 .M_{32}$

$K_{v3} = K_1 . M_{13} + K_2 .M_{23} + K_3 .M_{33}$

Similarly J_{h1}, J_{h2}, J_{h3} are written.

For a double circuit line,

$K_{v1} = K_1 (M_{11}+M_{14}) + K_2 (M_{21}+M_{24}) + K_3 (M_{31}+M_{34}) + K_4 ((M_{41}+M_{44}) + K_5 (M_{51}+M_{54}) + K_6 (M_{61}+M_{64})$

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$K_{v6} = K_1 (M_{13}+M_{16}) + K_2 (M_{23}+M_{26}) + K_3 (M_{33}+M_{36}) + K_4 ((M_{43}+M_{46}) + K_5 (M_{53}+M_{56}) + K_6 (M_{63}+M_{66})$

Similarly J_{h1} ... J_{h6} are written.

$[M] = [P]^{-1}$

$[P]$ = $n \times n$ matrix of Maxwell's potential coefficients

$P_{ii} = \ln (2H / r_{eq})$, $P_{ij} = \ln (I_{ij} / A_{ij})$

H = Height of the conductor above the ground

$r_{eq} = R (N. r / R)^{1/N}$

R = Bundle radius

r = radius of each sub conductor

N = number of sub conductors in bundle

I_{ij} = distance between conductor i above the ground and image of conductor below the ground

A_{ij} = aerial distance between conductors i and j

4. MODELING OF OVERHEAD HIGH VOLTAGE TRANSMISSION LINES AND HUMAN BODY

4.1 Single Circuit Horizontal Transmission Line

The single circuit horizontal conductor configuration proposed in this paper subject to voltage of 400kV.The transmission line is modeled as 3 phase conductors system with 13.2mm diameter placed at a distance of 15m above the ground and is considered for voltages of 400kV and 720kV for bundle conductors in 3 phase systems as shown in Fig-1, where each phase consists of two conductors, the distance from phase conductor to ground is 15m, the distance from guard cable to the ground is 20m and separation between two adjacent phases is 8.7m [4].

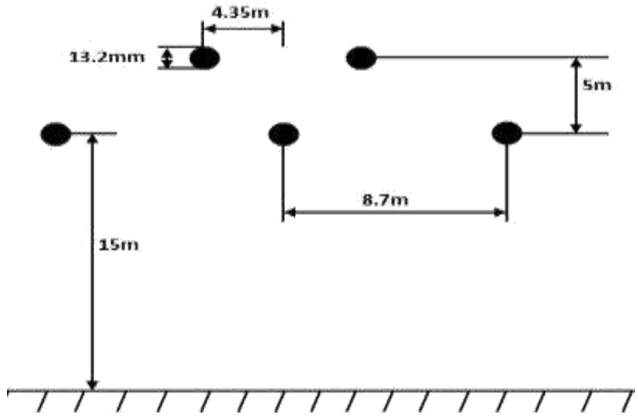

Fig -1: Single circuit horizontal transmission line configuration [4]

4.2 Single Circuit Triangular Transmission Line

The single circuit triangular transmission line configuration is shown in Fig-2. The OTL is modeled as 3 phase conductors system with 13.2mm of diameter and it is considered for a sinusoidal voltage with levels of 400kV for a bundle conductors in three phase system.

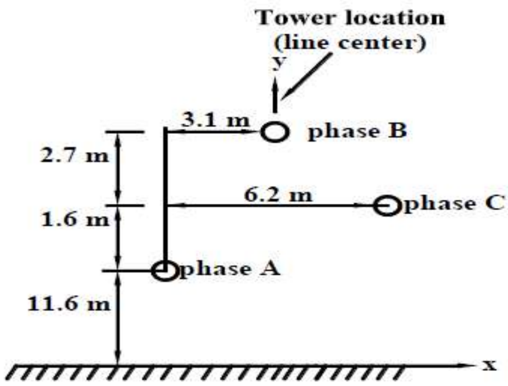

Fig -2: Single circuit triangular transmission line configuration [7]

4.2 Double Circuit Transmission Line

The double circuit overhead line (one at each side of the tower) is shown in Fig-3. The OTL is modeled as 3 phase conductors system with 13.2mm of diameter and it is considered for a sinusoidal voltage with levels of 400kV for a bundle conductors in three phase system.

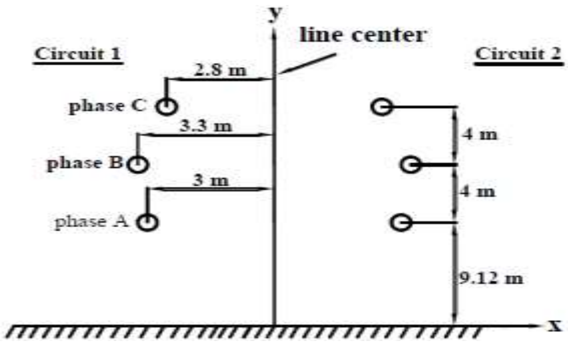

Fig -3: Double circuit transmission line configuration [7]

4.3 Modeling of Human body

The human body is considered as a conducting body because of large conductivity and permittivity. The height of the human body is considered as 1.76m and divided into blocks shown in Fig -4 and the value inserting in each block is the relative dielectric constant of organ shown in Table -1.

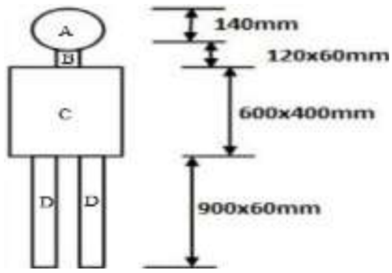

Fig -4: Human body model [7]

Table -1: Dielectric constants of Human body organs [4]

Mark	Organ	Dielectric constant
A	Brain	1.21E7
B	Other tissue	1.11E7
C	Lungs	5.76E6
D	Legs	1.77E7

5. MODELING OF OVERHEAD HIGH VOLTAGE TRANSMISSION LINES AND HUMAN BODY

The accurate computation of electric field distribution can be computed using finite element method. The transmission line and objects model are designed using FEMM 2D software package. The steps involved in the analysis are:

1. Create the geometry of the model
2. Assigning the materials
3. Assigning boundary elements
4. Assigning boundary conditions
5. Triangular mesh of the study domain
6. Solve using Bela solver for Electric field

5.1 Electric field analysis of human body placed under Single circuit horizontal transmission line

The single circuit horizontal conductor configuration and human body geometry is created and solved using FEMM software and equipotential distribution for 400kV is shown in Fig -5.

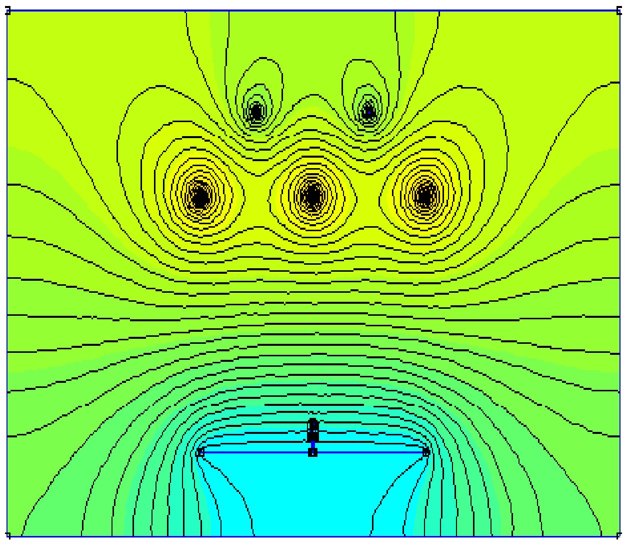

Fig -5: Equipotential lines distribution for 400kV Single circuit horizontal transmission line configuration

From the result analysis the maximum electric field intensity of human body obtained from 400kV single circuit horizontal transmission line is 14.294 kV/m at a potential of 3.442kV. The electric field intensity and potential results varied based on the distance from center of the axis is shown in Chart-1 and Chart -2.

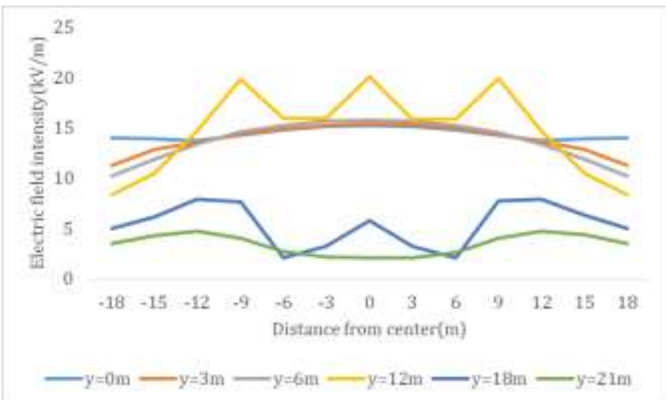

Chart -1: Variation of Electric field intensity based on distance from center of axis of horizontal transmission line

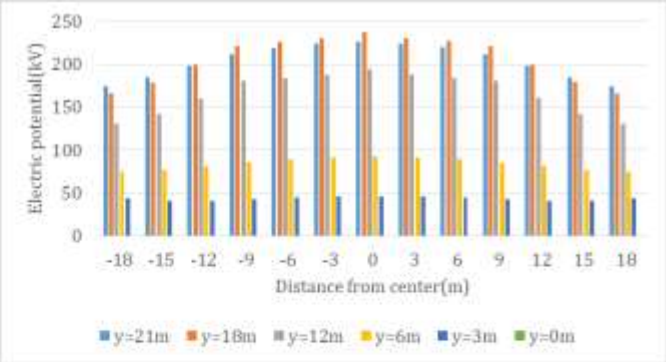

Chart -2: Variation of Electric field potential based on distance from center of axis of horizontal transmission line

From chart -1 ,it is observed that the electric field intensity is maximum at y=12m because the point is very near to the transmission line conductors and minimal electric field effect is observed at y=21m as the point is placed above the conductors. The electric field intensity will be more when the object is placed near to the transmission line and less when object is placed far away from the transmission line and from chart -2, it is observed that the electric potential is maximum at y=18m.

5.1 Electric field analysis of human body placed under Single circuit triangular transmission line

The single circuit triangular conductor configuration and human body geometry is created and solved using FEMM software and equipotential distribution for 400kV is shown in Fig -6.

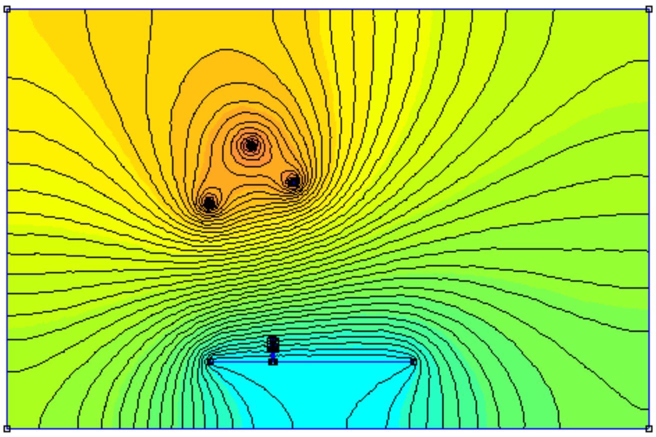

Fig -6: Equipotential lines distribution for 400kV Single circuit triangular transmission line configuration

From the result analysis the maximum electric field intensity of human body obtained from 400kV single circuit triangular transmission line is 22.043 kV/m at a potential of 0.893kV. The electric field intensity and potential results varied based on the distance from center of the axis is shown in Chart-3 and Chart -4.

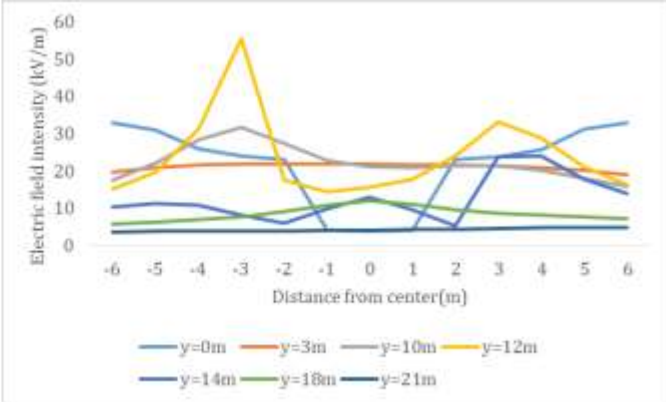

Chart -3: Variation of Electric field intensity based on distance from center of axis of triangular transmission line

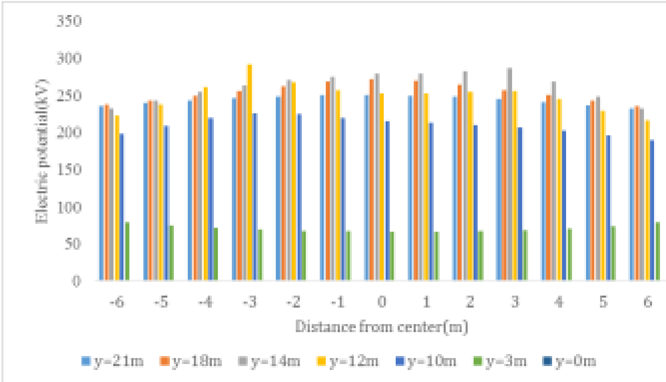

Chart -4: Variation of Electric field potential based on distance from center of axis of triangular transmission line

From chart- 3 it is observed that the electric field intensity is maximum at y=12m because the point is very near to the transmission line conductors and minimal electric field effect is observed at y=18 and 21m as the points are placed above the conductors. The electric field intensity will be more when the object is placed near to the transmission line and less when object is placed far away from the transmission line and from fig.6.5, it is observed that the electric potential is maximum at y=12m .

5.3 Electric field analysis of human body placed under double circuit transmission line

The double circuit conductor configuration and human body geometry is created and solved using FEMM software and equipotential distribution for 400kV is shown in Fig -7.

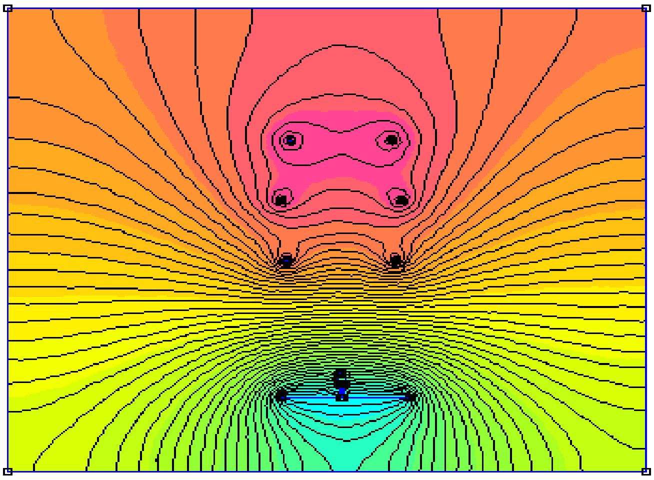

Fig -7: Equipotential lines distribution for 400kV double circuit transmission line configuration

From the result analysis the maximum electric field intensity of human body obtained from 400kV double circuit transmission line is 39.125 kV/m at a potential of 3.286kV. The electric field intensity and potential results varied based on the distance from center of the axis is shown in Chart-5 and Chart -6.

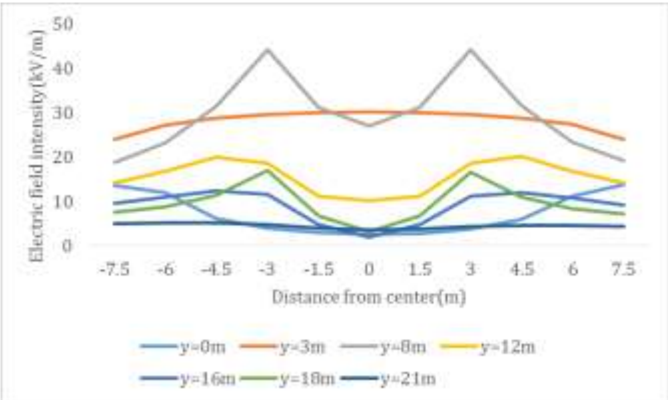

Chart -5: Variation of Electric field intensity based on distance from center of axis of double circuit line

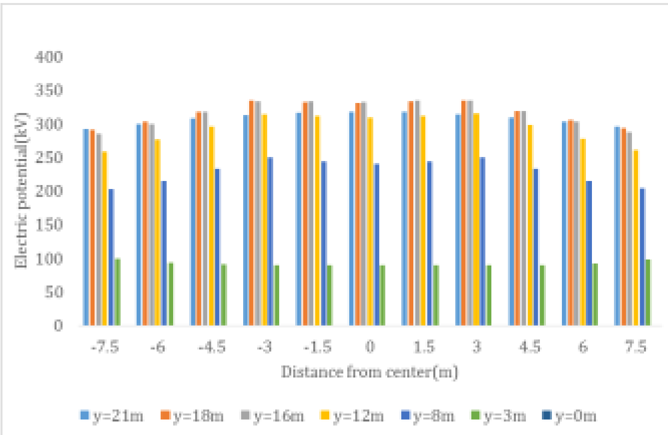

Chart -6: Variation of Electric field potential based on distance from center of axis of double circuit transmission line

From chart -5 it is observed that the electric field intensity is maximum at y=8m because the point is very near to the transmission line conductors and minimal electric field effect is observed at y=21m as the point is placed above the conductors. The electric field intensity will be more when the object is placed near to the transmission line and less when object is placed far away from the transmission line and from fig.6.12, it is observed that the electric potential is maximum at y=18m .

6. CONCLUSION

The 400kV transmission line of different configurations and human body are modeled using FEMM software and human body is directly placed under the transmission line to determine the effect of electric field. On comparing the electric field intensities on human body from different transmission line configurations the maximum electric field effect distribution is observed from a double circuit transmission line configuration and minimal effect from a single circuit horizontal transmission line. The electric field intensity will be more when human body is placed near to the transmission line and less when human body is placed far away from the transmission line and if the field effect is minimum the health hazards effecting humans will be less.

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