Optimization of Transmission Line Right-of-Way

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***Abstract*— A specific land is required to design the transmission line to construct effectively and maintain properly is called right of way of transmission line. It is calculated by considering mainly three electrical quantity related transmission line such as electric field, magnetic field and radio interference. Corona effect is considered for the evolution of right of way. By considering these parameters, it provide idea related to effect surrounding the area nearby transmission line.**

Keywords- Transmission line, electric field, magnetic field, audible noise, radio interference, right of way

I. INTRODUCTION

Day by day demand of electricity is increasing rapidly and hence it is important that large amount of power is generated to fulfil the power requirement. Power is generated by thermal, hydro and nuclear plant. Running cost of the hydro plant is less but it is located far away from the populated area as it is only available in hilly area. Running cost of the nuclear power plant is also low but it is also located far away from the populated area due to safety reason. It is important to transmit bulk power as much as possible to fulfil the requirement of demand of electricity and for that power should be transferred at high voltage. When the power is transferred at high voltage, some hazardous effect can be occurred in surrounding area. It was found true for the group of people who have opposed the reconstruction the transmission line. So, it is important to prevent the living population nearby this area and living creature as well, some strip of land is required to be vacant nearby transmission line.

This vacant area covered by transmission line is called transmission line right of way. Right of way = Width of tower + 2(width of safety region)

ROW= WT+ 2WR

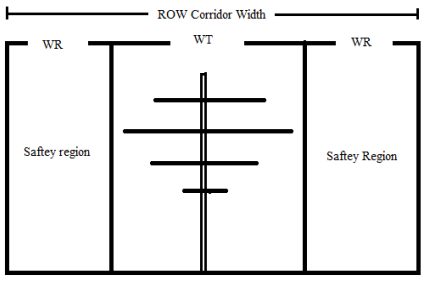

Fig. 1. Transmission line Right of way

II. RESEARCH BACKGROUND

A. Analysis and Design of Vertical and HorizontalConfigurations of Cross-arms in A Transmission line tower

As a result it's noted that if there is total requirement of six conductor wire, in vertical configuration there is three cross armed each carrying two conductor wire while in horizontal configuration there will be only two cross arms on top and bottom which will carry four and two conductor wire respectively.

In this research following work has been done:

- Calculation sag tension for conductor and ground wire using parabolic equation
- Tower is configured by keeping in mind all electrical and structure parameter
- Reliability, security, and safety pattern has considered first.
- The wind loading is calculated on the face of the both the tower.
- Tower member are designed as angle sections.

B. Radio Interference

It is one type of noise which occurs in the AM radio reception which standard broadcast band is from 0.5 MHz to 1.6 MHz it cannot replaced by FM band. Radio interference is normally expressed in millivolts per meter or decibels [1].

C. Comparison of Magnetic-Field Distribution of Noncom pact and Compact Parallel Transmission-Line Configurations.

With the increasing demand of electricity contradict the increasing demand of securing land corridor of transmission line. In this research paper investigation of alternative option of parallel line point of view of the magnetic flux density and current Carrying conductors of the transmission line. There are different alternative options are available such as converting three phase double circuit to six phase circuit. Second alternative is to building complex six phase circuits. This paper will show the compact -compact combination of parallel patterns for the new project. This project consist of high level of electrical magnetic field but still it's not beyond the maximum level. Over the years, potential hazardous nearby transmission line for the human being and animals to working and leaving near transmission line. It is investigated

that high level of electric magnetic field cause cancer in world but still it is not defined yet. To cope up with this hazardous, guideline has provided by World Health Organization (WHO). So while designing the transmission line, objective must be developed the way that its effects should be minimum occurred. High level of magnetic field occurred impact on environment which is very challenging for the electrical and technical team. For that, many studies and research has carried to evaluate the magnetic field at different transmission line for the different signs. In this paper, magnetic field is estimated for under and far from the two transmission lines with different arrangements.

D. Calculation of Electric and Magnetic Field Safety Limits Under UHV AC Transmission Lines.

Define With the increasing population and industrialization, the increasing demand of power is important. Ac transmission is the main source to meet the requirements of energy demand [6].

Considering the human body as a cylindrical structure of the different body parts ,where radius of the body part is r and conductivity is σ is related to the flux density at frequency f. Under UHV transmission lines, activates of human being is hazardous from different angle related to safety. Safety limit for electric filed and magnetic field depends on the height and spacing of the overhead conductors.

Horizontal configuration for more suitable for the overhead cable as safety limits violations are larger than triangular conductor configuration. The right of way 1000kV transmission line has been calculated to be around at 96m and for the 1200kV line it is to be noted at 104m form the ground level. It is observed that the magnetic field of the UHV transmission line for the horizontal configuration increase with the increase in SIL level.

E. Assessment of overhead transmission line right of way in Iran

All countries have their specific standards of corridor around overhead transmission line as a right of way [3]. This explanation divided into mainly two section. First priority is preservation which is directly connected to the safety and security. So, system operators should have been stopped the activities which can disturbed the safety and security in satisfaction level. Electric field and magnetic field exist near transmission line. However, there is not any theory and scientific reason which can prove that it is not harm to animals or human being. So, it is good to establish to rules and regulations to reduce the possible danger.

F. Row standard in Iran

Row determination in exiting standard is level of voltage of length of span. Furthermore, insulator, conductor, tower type, climate conditions of region. In regard to 20kV lines, air temperature is important factor in calculations in transmission line design while in high level due to bigger cross section and extensive lands with long spans, different factors such as thickness of ice and conductor cross section are more effective. So in this research paper, 63kV as per the ROW is addressed while 20kV for the research.

G Row calculation

Electrical calculation results, Mechanical Factors, Assessment of mechanical factors in different zones in Iran. By using prepared software, electrical filed is calculated for various distance for transmission tower from distance. In research it is found that specific distance acceptable limits 5kV/m. EMF limits should be added to conductor swing factor. It can be used for tower ranking in different climate and voltage levels.

H. Electric Field Mitigation under Extra High Voltage Power Lines

In this research paper, the mitigation of electric field for extra high voltage transmission line lines by using mainly two methods named active and passive shield wires.

To reduce the hazardous effect it is important to analyze the electromagnetic filed on the ground level is the most objective to minimize the effort at ground level. Most of these effect occurs at ground level and it is the function of the magnitude of the electric filed at 1m above the ground level. One of the most approach to use active and passive shield wires underneath of the line conductors. Previous workers investigated the effect of field effect by passive shield wires. It is important to support the shield wires at the required site to mitigate the electric filed. Charge simulation method has many advantage for the calculation of electric filed [2]. This method is very successful to solve the high voltage transmission line with and without active and passive shield wires.

I Analysis and Design optimization of transmission line based on electric and magnetic fields for different line configuration

Overhead transmission line required some amount of strip land as a right of way. These strips are related to different aspects such as electric and magnetic field. It is important to determine the maximum value of electric and magnetic field at the ground surface of the transmission line. To evaluate this performance two different vertical and horizontal configuration to analysis the transmission line. Next step is to changing parameters of the line configuration for giving best performance and involving minimize the cost is identified. It is optimized by applying the compact tower design.

Power demand has increased in the last decades and fulfill the power demand, transmission line is important part of the power system. As power generation are too far from the end users, power to consumer is only possible through grid of transmission and distribution lines.to transferred the effective amount of power it is important to transferred high voltage power and therefore transmission line network needs to be at high voltage. Electric and magnetic field plan an important role in transmission line design and operation. This high amount of electric field and magnetic field can affect the nearby living creature due to corona effect. So, it is important to analysis electric filed for the new constructing lines or any past exiting lines to avoid this hazardous problem as this field can make very bad habits on the living creature. For that it is important to design transmission line right of way.

J. Finite element analysis method

Finite element method is the significant potential to solve the mechanical and civil problem as well to modeling it. In the recent time, application of this method is used at its peak potential. Furthermore, its most exciting use of this technique is solve the problem such as interaction of the fluid structure, thermochemical problems, biomechanics, biomedical engineering etc. there are many applications are developed in the last decades but their commercial application is yet to be

proved While solving this differential equation initial condition.

III. RESEARCH METHODOLOGY

To achieve the aim and objectives of this project, different methods, parameter calculations and software will be used to compare the line configuration and to check their possible outcomes for this project. First, here in this project different line configuration will be analyzed by finite element analysis method. As different line configuration in this world are used to design the transmission line. As the Voltage level of the transmission line increased, intensity of the electric field and magnetic also increased which affects more in the surrounding area. Therefore, it is necessary to find the appropriate line configuration which produced lesser electric field and magnetic field. Here there are five types of line configuration will be considered at the ground level. Line configurations are listed below.

1. Horizontal configuration,
2. Delta configuration,
3. Davit configuration
4. Vertical configuration,
5. L type configuration

Above listed different configurations will be analyzed in FEMM software at the same height from the ground level.

- Electrical field for Horizontal configuration

In this type of configuration, all three conductor arrangement is horizontal. This all conductor are placed at same distance from the ground. This configuration is best for the analysis of electric field, magnetic field for it's simple arrangement.Due to its less height it is easy to construct.

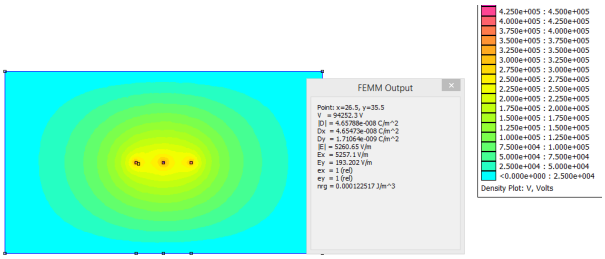

Fig. 2. Electrical field for Horizontal configuration

Electric field around the horizontal transmission line configuration is shown in below Fig. 2. Magnetic field around the horizontal transmission line configuration is shown in below Fig. 3. The same for delta configuration are shown in fig. 4 and Fig. 5. Red line in the Fig. 5 shows the center line of tower figure.

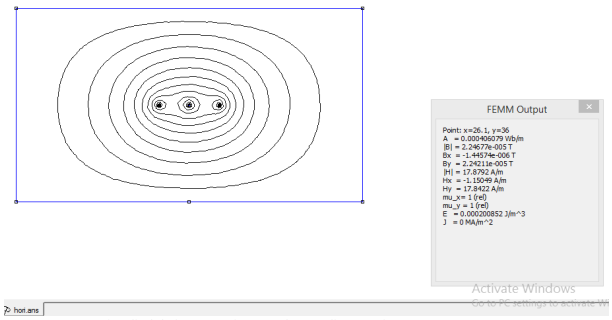

Fig. 3. Magnetic field for Horizontal configuration

- Delta configuration

In this type of configuration, all three conductors are in delta arrangement. Delta configuration tower is higher than horizontal configuration but lower than another configuration.

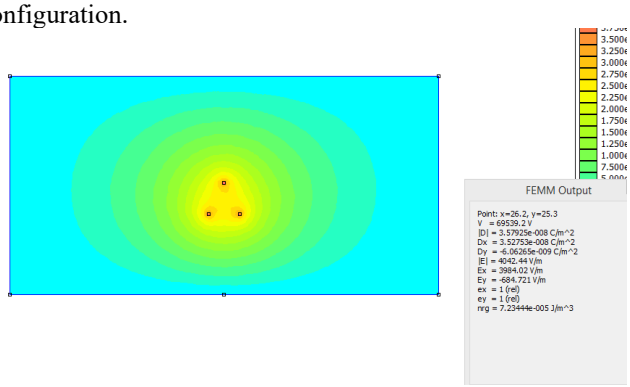

Fig. 4. Electric field of Delta configuration

- Magnetic field for Delta configuration

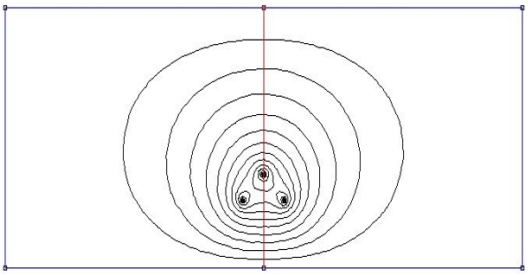

Fig. 5. Magnetic field for Delta configuration

IV. INTERPRETATION OF RESULT

Different type of transmission line configurations are used in the world for transmission line design. Voltage level is different for different for transmission lines. As voltage level increase, electric field and magnetic field affects the surrounding area. Therefore, it is necessary to find which transmission line has lesser electric field and magnetic field. Here five types of transmission line configurations analyzed by FEMM software to find the values of electric and magnetic field. For this analysis minimum distance from ground is 13m and phase spacing is 11m, radius of conductor is 0.01m, voltage is 400kV, Right of Width is 52m and current is 1kA is taken. Here all values obtained by FEMM software are given in the below table.

By finite element analysis method, it is conclude that delta configuration has lower electric and magnetic at the edge of right of way. Hence, we can say that Delta configuration is better line configuration in terms of electric and magnetic field.

TABLE I. E/B VALUES OF CONFIGURATIONS

Type of configuration	Electric field E(In kV/m) at 26 m	Magnetic field B (in µT at 26 m)
Horizontal	5.2	17
Delta	3.042	15
Vertical	4.31	21.1
Davit	3.51	17.6
L type	3.44	16.1

V. CALCULATION OF ELCTRIC FIELD AND MAGNETIC FIELD

Electric filed and magnetic field have some adverse effects on human being, animals and living plants surrounding the transmission line. This EMF can affects the human being for short term and long term health problems such as headache ,fatigue, anxiety, insomnia, burning skins are short term health problems and threat of DNA ,threat of cancer , threat of Leukemia are long term health problem.

It is absolutely important to prevent the human being and other living creatures form this hazardous health problems form electric field and magnetic field. Research organization establish the limit of electric filed and magnetic field. As per this research organization, maximum electric field limit exposure at 50Hz frequency for general public is 5kV/m and for occupational exposure is 10kV/m [5]. According WHO safety limit for the human being and other living creature near transmission line is 2kV/m. Magnetic field exposure limit at 50Hz frequency for general public is 200µT and for occupational is 1000µT. Therefore, an adequate right of way has to provide to transmission line in a way that its adequate right of way is lesser than its maximum permissible limit and hence calculation of electric field and magnetic field is much important.

Transmission line parameters are as under given the below.

- Single circuit horizontal line
- Line voltage V = 735 kV,
- Height of conductor from ground H = 20 m,
- Phase spacing S = 14 m,
- Number of sub-conductor N = 4,
- Bundle spacing B = 0.4572 m,
- Sub-conductor diameter d = 0.0305 m

An electric field analysis is done by MATLAB programming.

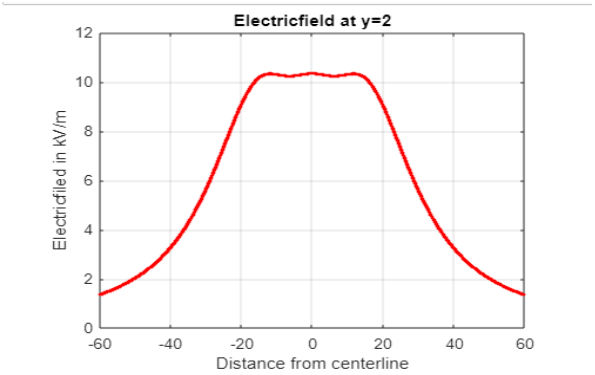

Fig. 6. Electric field at 2m above from ground

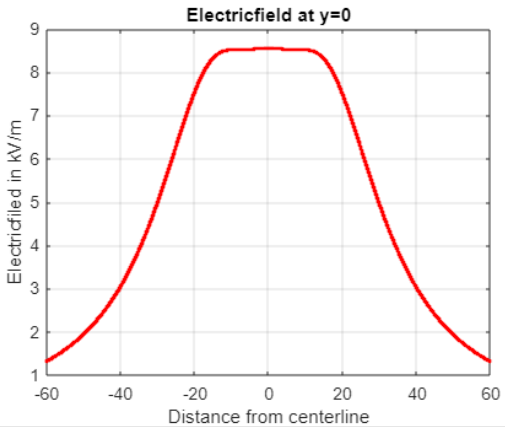

Fig. 7. Electric field at ground

Here, by comparing both above graph, Electric field at ground (y=0), 1m above from ground (y=1) and 2m above from the ground (y=2) at the distance of 40m from the center conductor it can be seen that the values of electric field are approximately 3kV/m and 2.6kV/m respectively. We can say that electric field intensity is decreasing as height is decreasing.

Change in number of sub conductor N=2 at 2m above from the ground.

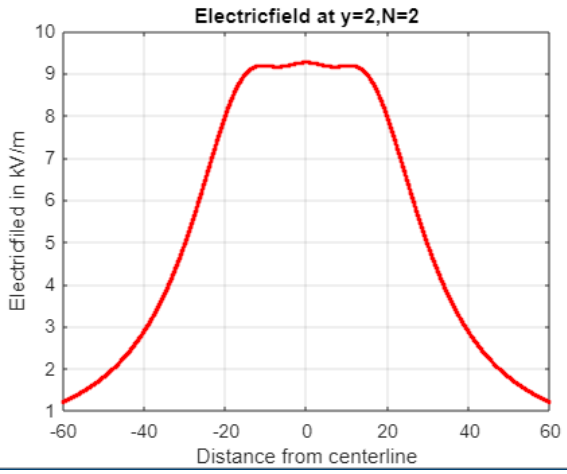

Fig. 8. Electric field for N=2

Calculation of Magnetic field at ground (y=0) and 2m above from ground (y=2).

The data for the MATLAB programming is given below.

For Single circuit horizontal line.

- Load power P = 1860 MW,
- Line voltage V = 735 kV,
- Current I = 1.4626 kA,
- Height of conductor from ground H = 20 m,
- Phase spacing S = 14 m.

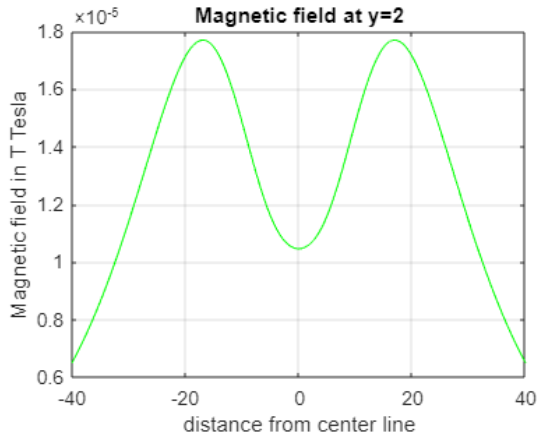

Fig. 9. Magnetic field at 2m above from ground

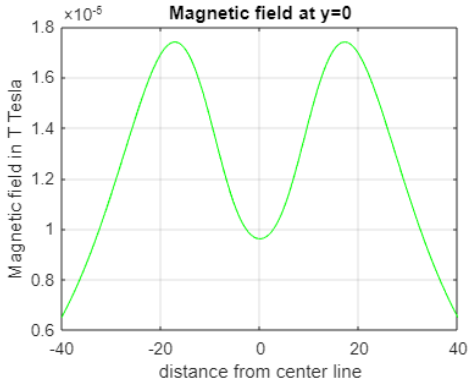

Fig. 10. Magnetic field at Ground

By comparing above two graphs at middle conductor, Magnetic field at ground and 2m above from ground is slight decreasing with decreasing distance from the ground.

VI. INTERPRETATION OF RESULTS

TABLE II. CORONA EFFECT: AUDIBLE NOISE AND RADIO INTERFERENCE

Distance from center conductor in meter (x)	Electric field (kv/m) for H=20m,S=14m,B=0.45m N=4,D=0.0305m	Ev(kv/m) for Number of sub conductor=6	Ev(kv/m) for Bundle spacing =0.35 m	Ev(kv/m) for Diameter=0.0406m
45	2.49	2.69	2.41	2.52
46	2.37	2.57	2.20	2.40
47	2.27	2.45	2.20	2.30
48	2.17	2.35	2.10	2.19
49	2.07	2.24	2.01	2.10
50	1.90	2.15	1.92	2.01
51	1.82	2.06	1.84	1.93
52	1.75	1.97	1.77	1.89
53	1.68	1.89	1.70	1.85
54	1.65	1.82	1.63	1.82

In high transmission line corona take place when the voltage gradient on the conductor surface is go beyond its breakdown strength of the surrounding air. Because of corona, such adverse effect observed such as on transmission line such as corona losses radio interference and audible noise etc. In any given transmission line, some factors which are affecting on corona are line configuration, type of conductor, surrounding weather and conductor surface. Therefor 50Hz transmission line has lesser corona as compared to 60Hz and DC power transmission line has lesser corona as compared to AC power transmission line.

Audible Noise

Audible noise is sound generate surrounding the transmission line when corona occurs. Therefore, certain limit has been set for maximum audible noise at the edge of right of way.

No complaints: less than 52.5 dB

Few complaints: 52.5 to 59 dB

More complaints: greater than 59dB

Different factors are affecting the audible noise which are below.

- Surface voltage gradient of the conductor,
- Number of sub-conductors,
- Diameter of conductor,
- Aerial distance
- Climatic condition

Audible Nosie at ground level

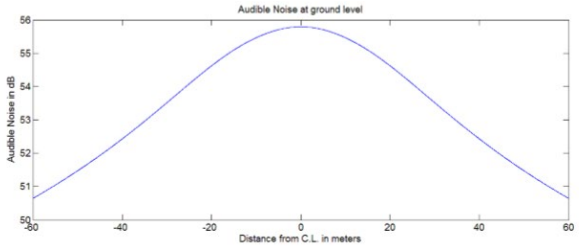

Fig. 11. Audible Noise at ground level

Audible noise when the change in diameter

Change in sub conductor Diameter has somewhat effect on audible noise. Here, I have chosen two different sub conductor diameter 0.0305m and 0.0406m.

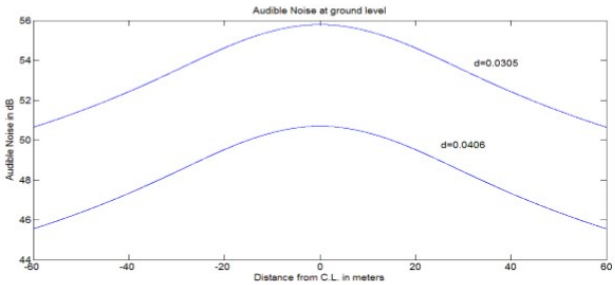

Fig. 12. comparison of AN for Two different sub conductor

From the above plot it can be seen that Audible noise is decrease with increase in diameter.

Radio interference

Radio interference is noise that happen because of AM (Amplitude modulation) radio. Standard broadcasting band of AM radio is 0.5 MHz to 1.5 MHz High voltage transmission line also cause the radio interference [4]. So, to prevent from

the radio interference the edge of right of way is 40dB for 11MHz.

Several factors are affecting the RI are.

- Diameter of conductor d in cm,
- Maximum surface voltage gradient on conductor in kV/cm,
- Aerial distance,
- Climatic condition.

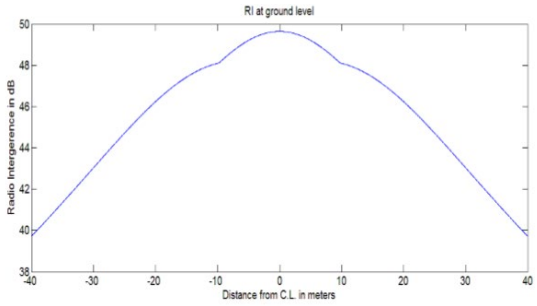

Fig. 13. comparison of AN for Two different sub conductor

It can be seen from the plot that RI is highest under the central conductor where it has litter decreasing at outer conductor configuration.

Effect of Electric field with different radios of sub conductor which are practically used in.

Here, I have chosen three different Aluminum alloy conductors which has different diameter and different electrical properties as per the Australian standard. All data has given in below table.

TABLE III. DATA FOR THREE DIFFERENT ALLOYS

Conductor type	**Krypton**	**Lutetium**	**Neon**
Diameter (m)	0.0325	0.0350	0.0375
Cost (per/km)	$7500 AUD		
Current carrying capacity at 2m/s wind	627	688	750
Dc resistance per km at 20 ° C (ohms)	0.189	0.163	0.142
Weight/km (kg)	4331	3892	4005

In the Table IV given below, we have compared all three-aluminum alloy conductor's ROW, cost and cost benefit for the 100km transmission line.

VII. CONCLUSION

By finite element analysis method, it is concluded that delta configuration has lower electric and magnetic at the edge of right of way. Hence, we can say that Delta configuration is better line configuration in terms of electric and magnetic field.

TABLE IV. COST AND COST BENEFIT FOR THE 100KM TRANSMISSION LINE

	Krypton	Lutetium	Neon
Electric field 2kV/m on one side	49m	49m	50m
ROW	98	98	100
ROW benefits	1m	1m	-
Length of line	100km	100km	100km
Reduced land occupation	10hectare	-	-
Average value of land	$87.8 million Dollar/hectare		
Total reduced cost	$878 million dollar		

Main factors affecting to right of way for any transmission line are electrical field, magnetic field, and corona effect which are analyzed in Matlab software for specific transmission line parameter and also observed the changing in line parameter values and analysed from the obtained graph how it affect the right of way width of transmission line. Here for 735kv transmission line above mentioned other parameters, we are getting right of way from 49m to 52m. We choose three different sub conductor as per the Australian standard and analysed it by Matlab software and conclude that right of way is very near to 49m and 50m by taking maximum safety limit of electric field 2kV/m. it is conclude that for above mentioned transmission line with use of krypton or lutetium its right of way is 49m and for Neon is 50m. Hence, we can say that we can reduce land by 1m in right of way.

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