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Mathematical Simulation for Right of Way Corridor for Overhead Transmission Line

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Abstract

Transmission lines play a vital role in the operation of a reliable electrical power system and that is why the transmission line system is considered as a lifeline system for power supply. The transmission line traverses across the length and breadth of the country, and it crosses all the natural reserves like forests, rivers, vegetation, mountains, etc., to make the system effective, Right of Way (ROW) plays a decisive role in the transmission line. But in today's growing population and economy, land acquisition for the construction of transmission lines is a major bottleneck. This leads to huge compensations for the utilities and a threat to the natural resources. This paper attempts to arrive at a mathematical simulation for effective ROW by studying different codal provisions and utility practices. The approach is made to make efficient use of the land available without compromising any relevant parameters for ROW.

Keywords: Ground Clearance, Mathematical Formulation of ROW, Right of Way, Tower Geometry, Transmission Line

1. Introduction

For an effective transmission line system, the right of way or the corridor plays a pivot role since the transmission line traverses across the country crossing natural resources, and rural and urban areas. The strip of land that is acquired by the utility for the construction and maintenance of its transmission line is generally termed the Right of Way. In today's growing economy and population, land acquisition has become a critical component of a transmission line. However, utilities are entitled to provide safe corridors for the surrounding structures and vegetation. Beyond construction, maintenance of this system also requires a clear path in case of repair works. The strip of land should be cleared off from trees, structures, and other obstructions for a safe line operation in turn providing safety to the public.

ROW corridor in an active transmission line is dependent on the following factors:

- Voltage rating
- Tower configuration
- Type of hardware fitting
- Swing of conductor –
  - Type of conductor
  - Sag and
  - Wind effect

Considering the above factors, the strip of land is cleared of vegetation and other obstacles along the route. This right-of-way acquisition has become a serious concern for the utilities when the line passes through urban areas, forests, etc.

Clearing vegetation, cutting off trees or acquiring land in urban areas is becoming challenging due to the increase in inhabitants and preservation of natural resources. Public awareness and its compensation have been rapidly growing in recent days along with the growing population and economy.

2. Right of Way Provision

The above picture depicts the conventional ROW corridor as per IS-5613 (code of practice for design, installation, and maintenance of overhead power lines).

It is recommended to clear all the obstacles that are present in the ROW corridor to conduct a complete survey,

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Figure 1. Transmission line Right of Way.

followed by a clearing of the obstacles along the corridor depending on the actual path taken. Clearing of obstacles is carried out as shown in Figure 2.

Theoretically, the assumptions behind arriving at the ROW width are not mentioned in any of the codal provisions and the values to be followed are provided in Table 1.

According to a technical report on the committee for finalisation of compensation regarding the ROW in urban areas in 2019, the report was made finalising the ROW values for plain, hilly and forest areas.

In the report, ROW is calculated based on a 35° deviation of sag of the conductor as well as a 35° deviation suspended I-insulator at 85°C temp. It also recommends taking 5.5 m minimum clearances between conductor to trees for 400kV lines for other kV voltage lines they have given approximate formulas to calculate minimum clearance.

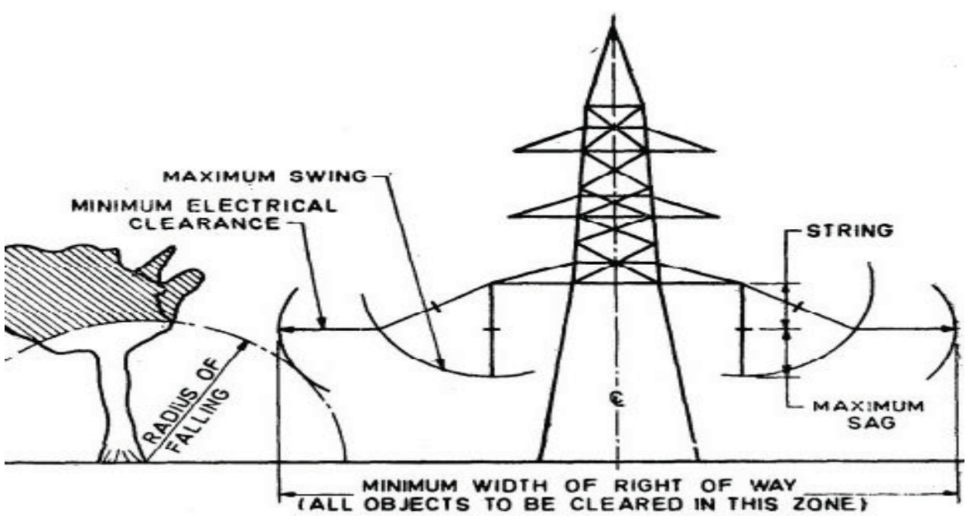

Figure 2. Line clearance (Right-of-Way) requirement.

Figure 3 shows how ROW is calculated, as it can be seen clearly for the I-string 35° angle is taken for both swing of an insulator as well as conductor for maximum sag value.

Figure 4 shows how ROW is calculated, for a V-string insulator unlike an I-string insulator it doesn't swing therefore the swing of the insulator is taken as zero while for the sag of conductor deflection, it is taken as 35°.

The values mentioned in the technical report also give values to be followed for compensation in cases where the line traverses through plain, forest and urban areas However,

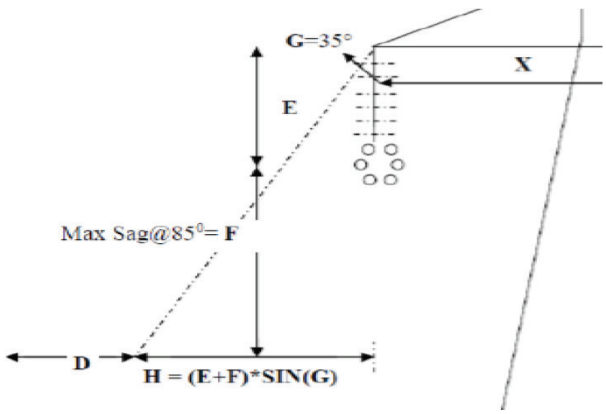

Figure 3. ROW for I-string insulator.

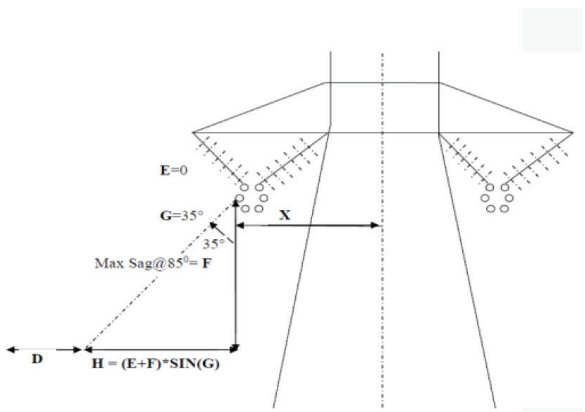

Figure 4. ROW for V-String insulator.

these values are adopted considering an ideal condition of similar span, sag, and a typical tower configuration.

Different countries follow different ROW values based on the expert study considering the land profile, vegetation, and land availability.

Following are a few country's ROW requirements:

In general, we can see that India is adopting the least width of the ROW for the transmission line.

Table 1. Specification for ROW in India

Voltage Level (kV)	ROW (in meters)
66	18
110	22
132	27
220/230	35
400	46
765	64
1200	89

Table 2. Specification for ROW in Georgian

Voltage Level (kV)	ROW (in meters)
1 or below	4
1-20	20
35	30
110	40
150/220	50
330/400/500	60

Table 3. Specification for ROW in Uzbekistan

Voltage Level (500kV)	ROW (in meters)
Horizontal configuration suspension tower single-circuit	85.6
Vertical angle tower single circuit three phase	96
Vertical configuration double circuit	145

Table 4. Specification for ROW in Saudi Arabia

Voltage Level (kV)	ROW (in meters)
69	28
110/115/132	34
230	44
380	50

Table 5. Specification for ROW in Rwanda Utility

Voltage Level (kV)	ROW (in meters)
0.4	3
15	12
30	12
110	25
220	30
400	50

Table 6. Specification for ROW in Australian Utility

Voltage Level (kV)	ROW (in meters)
Up to 33 kV	10 to 20
66	20 to 30
110/132	30 to 40
220	30 to 50
275	50 to 60
330	70
400	65
500	70

3. Mathematical Simulation for Optimising Row

In all the values mentioned above for the ROW, standard values are mentioned irrespective of the varying factors like tower configuration, hardware attachment type, tower span, etc., every transmission line of a particular kV rating in a particular country is obliged to stick to the prescribed values. The freedom to arrive at the ROW based on the tower type, span and wind pressure, there are no studies made.

Here in this study, an attempt is made to provide a mathematical simulation for ROW depending upon the varying factors mentioned above. The study is an attempt to put forward a topic for discussion or debate among the utilities to reiterate the concept of ROW. The idea arose concerning Saudi standard TSE-P-122.09 where the method of calculation for the same was depicted.

In this study, an approach has been made to formulate all the variables term mathematically and study the variation of ROW by changing the span length, insulator type, and mainly the wind effect keeping all other variables constant. Factors influencing ROW as mentioned in the figure mainly depend on the following factors in any transmission line:

- Distance of tip of cross-arm from the centre of the tower, i.e., tower configuration.
- The horizontal component of the swing of the insulator.
- Swing of maximum sag of conductor.
- Minimum clearance between conductor and trees.

If from the centre of the tower to the edge of ROW is expressed by E then the total width of ROW will be 2E, then E can be expressed as follows: -

where E is one side width of ROW.

$$E = A + B + C + D \ldots\ldots\ldots\ldots (1)$$

Where,

A = Distance of tip of cross-arm from the centre of the tower

B = (Length of suspended insulator (Li)) *sin(θ)

C = (Vertical Sag of conductor(S)) *sin(θ)

D = Minimum clearance between conductor and trees

So Mathematically ROW is given by:

According to the Saudi code:

$$E = A + Li * sin(\theta) + sin(\Phi) + 2.3 + 0.01 * \left(\frac{1.1 * Voltage(kV)}{\sqrt{3}} - 22 \right)$$

Where:

θ = 45º for I-insulator

Φ = vertical sag(S) @ EDT 927N/m2 wind pressure i.e. 67% wind condition

Considering the above calculation methodology in Indian conditions, an attempt for ROW calculation was made with the below assumptions.

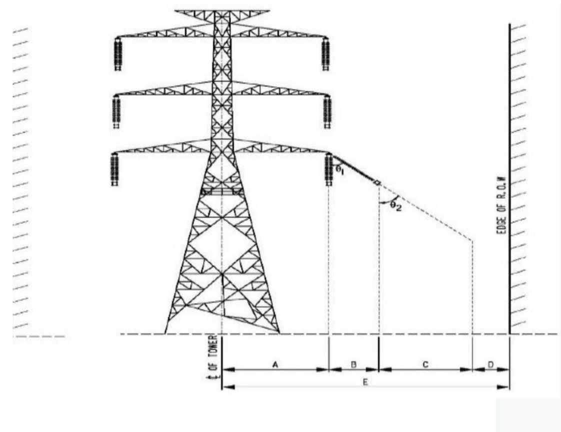

Figure 5. Calculation of row of single transmission line.

Table 7. Tower configuration

Particulars	Value
kV rating	400kV
Span Length	400 m
Type of insulator	"I"
Length of insulator	5.6 m
Max sag @ 85ºC	13.3 m
Sag @EDT and 36% wind pressure	7.74 m
Horizontal Clearance	5.6 m
Maximum Horizontal distance of Conductor attachment point from the centre of the tower	7.7 m

With these considered parameters, the study was carried out by reformulating the provisions provided in the code to effectively reduce the row values. The results are mentioned below for the discussion.

4. Result and Discussion

Considering the above parameters, with the mathematical simulation, ROW was calculated for varying span lengths. Since the span and the sag of the conductor are directly proportional, with the increase or decrease in span ROW value varies proportionally.

The below graph in Figure 6 indicates the variation of sag based on the span. It shows:

$$Sag \propto (Span\ length)^2$$

Table 8 indicates the % variation of ROW calculated based on the mathematical formula above for varying sag of conductor i.e., for varying span.

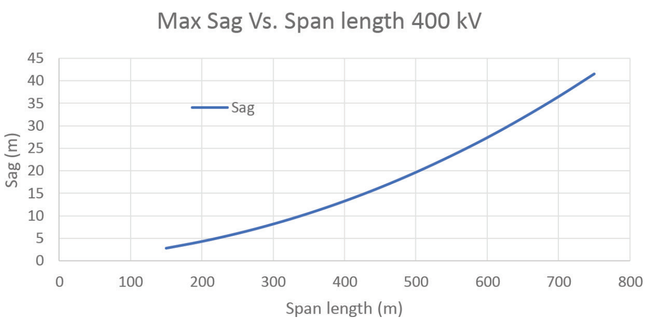

Figure 6. Variation of sag with span.

Table 8. ROW was calculated at 85 degrees and NIL wind

Span (m)	ROW as per Codal provision	ROW calculated (@85 & 0 Kg/m^2)	% Variation
150	46	34.07	-26%
200		35.79	-22%
250		37.83	-18%
300		40.22	-13%
350		42.96	-7%
400		46.07	0%
450		49.55	8%
500		53.41	16%
550		57.65	25%
600		62.24	35%
650		67.29	46%
700		72.69	58%
750		78.49	71%
800		84.67	84%

Extending our study, for similar cases above the variation in ROW by replacing I-string hardware fitting with V-string was studied.

Table 9 indicates the % variation of ROW calculated based on the mathematical formula above for V-string since the swing of the insulator is NIL for V-type.

The variations in ROW for varying spans show that the corridor shall be maintained the same throughout the line

Table 9. ROW calculated at 85 degrees and NIL wind with V-type insulator

Span (m)	ROW Followed in India (m)	ROW (@85 & 0 Kg/m^2)	% Variation
150	38	26.41	-30%
200		28.13	-26%
250		30.17	-21%
300		32.56	-14%
350		35.30	-7%
400		38.41	1%
450		41.89	10%
500		45.75	20%
550		49.99	32%
600		54.58	44%
650		59.63	57%
700		65.03	71%
750		70.83	86%
800		77.01	103%

and can be modified based on the varying span. In locations where ROW and its compensation are huge, utilities can adopt to lesser span and where the land is available higher span shall be adopted.

The study was further extended to find the impact of wind effects on the ROW calculation since the sag and the swing of the conductor are directly dependent on the wind condition.

For a particular wind zone tower, say WZ-4 the ROW for full wind conditions and diminishing Wind pressure was calculated. Concerning the technical report formulated in 2019, an attempt to find the reference of 35° for calculating the deflected sag position was carried out. It was found that the wind pressure equivalent to 44 kg/m^2 was supporting to 35° swing of conductor.

$$E = A + Li * sin\left(\theta\right) + S * sin\left(\Phi\right) + 2.0 + 0.3 * \left(\frac{Voltage\left(kV\right)}{33}\right)$$

Where,

$$\Phi = \tan^{-1}\left(\frac{Conductor\ Dia \times \text{Wind Pressure}}{\text{Unit Weight}}\right)$$

In which,

Wind pressure shall be considered as 44 kg/m^2 taking the reference of 35° as in the technical report.

Table 10. % Variation of ROW at 57°C and 44.17 kg/m².

Span (m)	Standard ROW	ROW (@57°C & 44.17 Kg/m²)	% Variation
150	46	33.49	-27%
200		35.12	-24%
250		37.09	-19%
300		39.43	-14%
350		42.12	-8%
400		45.20	-2%
450		48.65	6%
500		52.48	14%
550		56.70	23%
600		61.31	33%
650		66.31	44%
700		71.70	56%
750		77.48	68%
800		83.66	82%

The swing of the conductor is dependent on the most prevalent wind condition, it was attempted to replace the sag of the conductor with the sag at wind conditions which is generally considered as maximum sag.

The table above indicates the % variation of ROW for different spans considering the sag of 44 kg/m² wind pressure and 57°C temperature which is calculated based on everyday temperature (32°C) + conductor temperature (25°C), against the standard ROW value specified.

Hence from the results, it is evident that the predominant factor affecting ROW is the effects of wind and the mathematical simulation shall have the wind and its pressure as its major governing factor.

From the study, it is evident that ROW shall not be restricted to certain values as mentioned in the codal provision. It varies depending upon the span, sag, type of configuration, hardware fittings and mainly wind effects.

The ROW value will vary exponentially depending on the span variation. But if the trial is made to replace the hardware fitting, ROW can be limited in locations where there is huge demand for the corridor.

Also, as an alternative, the ROW shall be reiterated based on the sag at most prevailing wind conditions which would provide similar conservative ROW values like that of replacing hardware fitting.

5. Conclusion and Recommendation

From the study and the results obtained, we conclude that rather than restricting ROW to confirmed values efforts to recalculate the ROW based on the span and wind effects shall be taken into consideration.

It is also evident that this mathematical simulation will be a tool for the utilities to reorganise ROW where the land acquisition is a major concern without compromising on the safety of the public and the cost of the total project.

Furthermore, the below choices shall be made by the utility to optimise the ROW based on certain innovative design approaches like

- Adopting narrow base towers.
- Use of V-string fitting.
- Choice of low sag conductor.

For further scope of optimisation in ROW, we also propose to consider the corridor as shown in Figure 7, along the portion of the actual conductor position rather than clearing all obstacles in the ROW corridor. This in turn would preserve the natural resources and vegetation along the transmission line corridor.

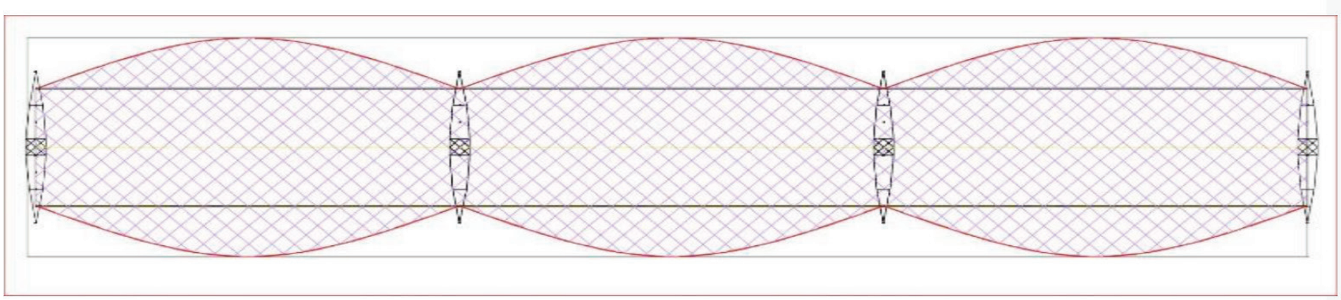

Figure 7. Proposed ROW width- scope of optimisation.

6. References

1. Sarkar S, Bhatnagar J. Laws of electricity in India. Orient Publishing Company; 2019.
2. Jatwa H, Tiwari V, Pahwa S. Comparative study of Indian and ASCE codes. International Journal of Innovations in Engineering and Technology (IJIET). 2014; 4(3).
3. Lalitha SVNL, Talati S, Yasaswini. Multi-voltage multi-circuit transmission tower. Indian Journal of Science and Technology. 2016; 9(33). https://doi.org/10.17485/ijst/2016/v9i33/95724
4. Gupta R, Malewar H. Right of Way (ROW) challenge in the construction of transmission lines; 2021.
5. Prasad S, Arora J. Guidelines for payment of compensation regarding Right of Way (RoW) for transmission lines in urban areas. Ministry of Power; 2021.
6. Ahluwalia PM, Rikh VN, Anand VD. Transmission line manual. Central Board Of Irrigation and Power. 1993; 268.
7. Power M. Guidelines issued by the Ministry of Power; 2015.
8. Jain RD, Ahuja MK. IS:5613(Part 1 and 2) Indian standard code for transmission line tower. Bureau of Indian Standards; 1993.