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Lightning Protection of Overhead 220kV/400kV Transmission Lines

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Abstract: **In this research the analysis of lightning leader strokes on transmission system is investigated. In this report general studies carried out to obtain analysis of 220kV/400kV and 765kV transmission line structure models. Some calculation has given which explains the configuration model of 220kV/400kV and 765k transmission line protectiveness. The main purpose of this report is about studying structure of generalized transmission lines which existing for commercial Benefits. Key results indicated in this work show that the lightning current amplitude, front time and the tower shielding angle must be considered in lightning protection studies.**

Index Terms: **Lightning, Transmission, flashover, IEEE model.**

I. INTRODUCTION

The performance of transmission lines when hit by lightning cause of unscheduled shutdowns of the lines. These shutdowns generate billing fines from energy companies. Also affect the image of these companies with their consumers. The lightning can damage the electrical system in the transmission line of high atmospheric discharge density since most of shutdowns are caused back flashover. There are several methodologies and input data for the calculation of performance of transmission lines against atmospheric discharges. These data characterization of discharge (amplitude, crest time, time half-wave, waveform). The process of connecting with electrical system modeling its response in spreading the outbreaks.

The lightning performance of transmission lines is very important for electric utilities around the world. Lightning is a major cause of outages of overhead lines. In transmission systems lightning is especially damaging, even in regions with both average lightning density and soil resistivity, since most trip outs are caused by back flashover. The available methodologies and input data for calculating the lightning performance of transmission lines share some common ground. Despite this comprehensive discussion, there are few studies presenting real transmission line performance data, facilitating the validation of proposed methodologies. In fact, there are not many papers comparing calculated values with results obtained from field experience.

II. MODES OF LIGHTENING FLASHOVER

For the practical study of the lightening protection and performance of transmission lines, it is convenient to define three modes or mechanism by which the lightning strokes can cause insulation flashover. Although related phenomena can be found in all three modes, they will be considered as essentially independent unless otherwise noted.

The induction IN mode is operative for strokes to earth near the line but not in contact with any element of it. The shielding failure SF mode is operative for strokes directly to the phase conductor. The back-flashover BF mode is operative for strokes directly to the shield wire or supporting structure.

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The induction mode is now quite generally considered harmless to the transmission lines. induction mode mechanism could be protected against and that direct strokes were certain to result in flashover on steel tower lines and massive structural damage on wooden pole lines. The economic value of the overhead static wire and concluded that it was beneficial on steel towers but harmful on wooden pole structures. With the advent of the cathode-ray oscillograph and the initiation of large field research programmers it became possible to access the relative roles of the IN and BF modes of flashovers objectively. Extensive studies led to conclusion that the IN mode was negligible in causing lightening outage on HV lines.

III. ANALYTICAL MODEL OF GENERALLY USED TRANSMISSION LINE

Shielding failure flashovers can be reduced to rare events by providing properly shielding conductors. Even poorly located shields wires failed to intercept some of the strokes to line and even poorly located shield wires intercept most of the strokes. To the line and even popularly located shield wires failed to intercept some of the strokes having prospective currents to earth above minimum amplitude the design problem then consist of steps required to locate the shield wires son to intercept strokes having prospective currents to earth above minimum amplitude. It is convenient to an analytical model which exhibits the relations between the structural and electrical parameters of the problems. The mean structural dimension of the line together with the means of striking distance of the stroke constitute the geometrical parameters. The complete analytical model consists of geometry together with an associated set of basic assumptions and mathematical relations.[7] and [9]

IV. DERIVATION FOR ESTIMATING CO-ORDINATES OF POINTS P1 & P2

The typical structure of the 220kV or 400kv transmission tower and 765kV transmission tower. Consider analytical model structure of 220kV transmission tower as shown in figure 1 in this paper.

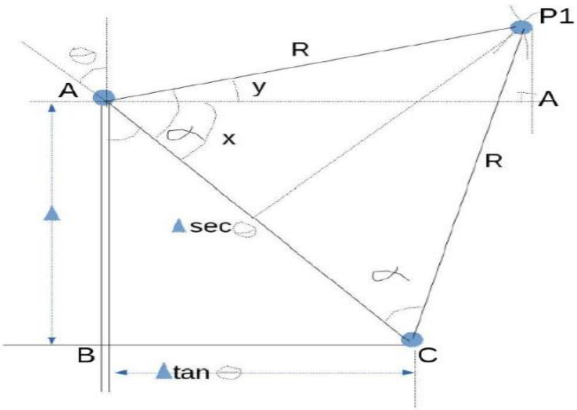

Figure 1: for calculating co-ordinate of P1

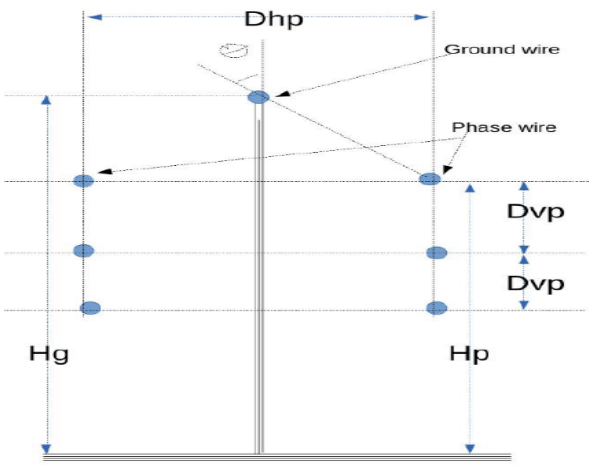

Figure 2: 220KV or 400kV transmission line

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V. STANDARD VALUES FOR CALCULATION

Generalized formula for Striking distance R is given as

$$R = aI_p^b + c$$

For IEEE standard Model values are

a=10 and b=0.65 and c=0 & Height dependent Rizk Model

$$a = 4027Hg^{0.41}$$

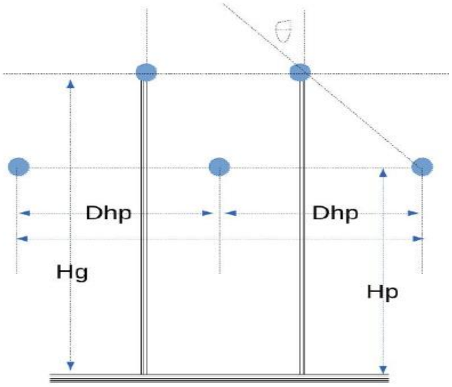

Figure 3: 765kV transmission line structure

and b=0.55 and c=0 voltage dependent model all values considered according to IEEE model. Where voltage given as

$$V = 5 * 10^6 I_p^{0.65}$$

VI. CALCULATION FOR 220 kV TRANSMISSION TOWER

Hp=7m, shielding angle = 20 degree.

Dvp= Phase to phase vertical distance = 6.7m

Dhp= Phase to phase horizontal distance = 12.6m

Calculations for IEEE model peak value of leader current 20kA. now

Hp = (7+(607*2)) =20.4m

$$\Delta = 17.309$$

$$Hg = Hp + \Delta$$

Hg = 38.82

$$R = 10I_p^{0.65}$$

Ip=20kA
R=70.092

so starting point P1 will be

$$x1 = Rcos(\Theta - sin^{-1}(\frac{\Delta sec(\Theta)}{2R}))$$

x1=66.22m and ending point will be

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$$x_2 = \sqrt{R^2 - (KgR - Hg)^2} + (\Delta tan\Theta)$$

x2=74.84m.

so, area of lightening strokes goes to phase conductor will be

$$a_p = \frac{(x_2 - x_1) * 100}{1000}$$
$$a_p = 0.862m$$

and area of lightening strokes goes to ground wire will be here

$$a_g = \frac{(x_1 - x_0 * 100}{1000}$$

$$x_0 = 0$$
$$a_p = 6.622m$$

Probability distribution function considering current 17.5-22.5kA

$$P(I_p > I_1) - P(I_p > I_2)$$
$$\frac{1}{1+\frac{I_1}{I_f}} - \frac{1}{1+\frac{I_2}{I_f}}$$

here If=31Ka, Therefore P=0.118, area lightning phase conductor

$$a_f = P * a_f$$
$$a_f = 0.0342m^2$$

So effective area of lightening on ground wire will be

$$a_{fg} = P * a_g$$
$$a_f = 0.7814m^2$$

if further we calculate for each current ranging from 10 to 100kA and add last column we get a numerical value in terms of number of lightening strokes immerges for 100m line per year.

Height dependent Rizk model peak value of leader current 20kA.

now Hp = (7+(607*2)) =20.4m

$$\Delta = 17.309$$
$$Hg = Hp + \Delta$$

Hg = 38.82

$$R = aI_p^b$$

Ip=20kA

$$a = 4.27Hg^{0.41}$$

a=19.14
b=0.55

so striking distance will be as

$$R = 19.14I_p^{0.55}$$

R=99.42, so starting point P1 will be

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$$x1 = Rcos(\Theta - sin^{-1}(\frac{\Delta sec(\Theta)}{2R}))$$

x1=96.17 and ending point will be

$$x_2 = \sqrt{R^2 - (KgR - Hg)^2} + (\Delta tan\Theta)$$

x2=101.301 area of lightning strokes goes to phase conductor

$$a_p = \frac{(x_2 - x_1) * 100}{1000}$$

$$a_p = 0.493$$

Lightning strokes goes to ground wire will be here

$$a_g = \frac{(x_1 - x_0 * 100}{1000}$$

$$x_0 = 0$$

$$a_g = 9.617m$$

Probability distribution function considering current 17.5-22.5kA

$$P(I_p > I_1) - P(I_p > I_2)$$

$$\frac{1}{1+\frac{I_1}{I_f}} - \frac{1}{1+\frac{I_2}{I_f}}$$

here If=31kA, Therefore P=0.118, area lightening phase conductor.

$$a_f = P * a_f$$

$$a_f = 0.0582m^2$$

So effective area of lightening on ground wire will be

$$a_{fg} = P * a_g$$

$$a_f = 1.1348m^2$$

VII. FURTHER CALCULATIONS FOR 765KV LINE

Dhp=phase to phase conductor distance = 9m

Hp= height of phase conductor above ground=12m

Hg= height of ground wire above ground =17.55m

Dg= ground conductor to conductor space= 12.82m

Calculations for Height Rizk model peak current ranging 10-00kA

now Hp = 12m

$$\Delta = 8.55$$

$$Hg = Hp + \Delta$$

Hg = 17.55m

$$R = aI_p^b$$

$$a = 4.27Hg^{0.41}$$

a=13.82
b=0.55

so striking distance will be as

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$$R = 13.82 I_p^{0.55}$$

so starting point P1 will be

$$x1 = Rcos(\Theta - sin^{-1}(\frac{\Delta sec(\Theta)}{2R}))$$

and ending point will be

$$x_2 = \sqrt{R^2 - (KgR - Hg)^2} + (\Delta tan\Theta)$$

so, area of lightening strokes goes to phase conductor will be

$$a_p = \frac{(x_2 - x_1) * 100}{1000}$$

and area of lightening strokes goes to ground wire will be

$$a_g = \frac{(x_1 - x_0 * 100}{1000}$$

1	current	Radius R=13.:	Starting point	Ending Point	area a1	area a2	probability dist	Effect area ae	effect ae2
2	10kA	65.285	63.63	64.155	0.0525	6.528	0.0618	0.0032	0.3932
3	15kA	81.59	79.27	79.043	-0.0227	8.159	0.0983		0.9109
4	20kA	95.583	92.67	91.619	-0.105	9.5583	0.118		1.0935
5	25kA	108.06	104.63	102.74	-0.189	10.806	0.119		1.2451
6	30kA	119.46	115.54	112.855	-0.268	11.946	0.1073		1.2397
7	35kA	130.033	125.67	122.194	-1.347	13.0033	0.0906		1.1386
8	40kA	139.942	135.16	130.92	-0.42	13.9942	0.073		0.9867
9	45kA	149.3	144.129	139.16	-0.496	14.93	0.0577		0.8316
10	50kA	158.216	152.65	146.98	-0.567	15.8216	0.0453		0.6915
11	55kA	166.73	160.81	154.44	-0.63	16.673	0.035		0.5628
12	60kA	174.904	168.63	161.603	-0.7027	17.4904	0.028		0.4722
13	65kA	182.776	176.17	168.49	-0.768	18.2776	0.022		0.3876
14	70kA	190.38	183.45	175.138	-0.831	19.038	0.0178		0.3265
15	75kA	197.74	190.45	138.57	-0.893	19.774	0.0144		0.2743
16	80kA	204.88	197.34204	187.81	-0.953	20.488	0.0188		0.2329
17	85kA	211.83	204.46	193.87	-1.013	21.1183	0.0097		0.1979
18	90kA	218.6	216.18	199.773	-1.068	21.86	0.008		0.1684
19	95kA	225.198	222.95	205.52	-1.126	22.5198	0.0067		0.1452
20	100kA	231.64		211.143	-1.18	23.164	0.0056		0.1249

Table 1: calculation table of old striking distance

$$x_0 = 0$$

Probability distribution function for considering current limit

$$I_1 to I_2$$

$$P(I_p > I_1) - P(I_p > I_2)$$
$$\frac{1}{1+\frac{I_1}{I_f}} - \frac{1}{1+\frac{I_2}{I_f}}$$

here If=31kA, here Kg=0.5, area lightning on phase conductor

$$a_f = P * a_f$$

So effective area of lightning on ground wire will be

$$a_{fg} = P * a_g$$

calculation Table for current ranging from 10 to 100Ka. effective area of phase conductor is negative. It proved this height dependent model effective for protection against shielding failure.

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VIII. CALCULATIONS CONSIDERING IEEE STANDARD VALUES

$$R = aI_p^b$$ AD-HR

here a=10 and b=0.55

$$V = 5 * 10^6 I_p^{0.65}$$

Calculate v/R column this ratio will only applicable for ground wire but for phase conductor V/R ratio will be different there will be change in striking distance because of this phenomenon

1	Current	Striking distance	Votage(V1)	Ratio(V/R
2	10kA	44.668	22.334*10^(6)	0.5*10^(6)
3	15kA	58.137	25.79*10^(6)	0.5*10^(6)
4	20kA	70.092	29.068*10^(6)	0.5*10^(6)
5	25kA	81.032	35.046*10^(6)	0.5*10^(6)
6	30kA	91.228	40.516*10^(6)	0.5*10^(6)
7	35kA	100384	45.614*10^(6)	0.5*10^(6)
8	40kA	109.98	50.421*10^(6)	0.5*10^(6)
9	45kA	118.73	54.993*10^(6)	0.5*10^(6)
10	50kA	127.15	59.368*10^(6)	0.5*10^(6)
11	55kA	135.28	63.577*10^(6)	0.5*10^(6)
12	60kA	143.15	67.64*10^(6)	0.5*10^(6)
13	65kA	150.79	71.576*10^(6)	0.5*10^(6)
14	70kA	158.23	75.398*10^(6)	0.5*10^(6)
15	75kA	165.49	79.398*10^(6)	0.5*10^(6)
16	80kA	172.58	79.119*10^(6)	0.5*10^(6)
17	85kA	179.52	82.748*10^(6)	0.5*10^(6)
18	90kA	186.31	86.293*10^(6)	0.5*10^(6)
19	95kA	192.98	89.761*10^(6)	0.5*10^(6)
20	100kA	199.52	93.159*10^(6)	0.5*10^(6)

Table 2: calculation table for new striking distance

from this table it is concluded that there will be constant striking distance for ground wire and there will be constant ratio of voltage and striking distance (v/R). There will be different striking distance for phase conductor for both positive and negative magnitude of the 765kV line so new striking distance will be given as

$$R_2 = Vg * \frac{(5 * 10^6 Ip^{0.65} \pm (\sqrt{\frac{2}{3}}))}{500 * 10^3}$$

for all values of current ranging from 10kA to 100kA. Further example considers following table from calculation table that there will be very small difference for new striking distance so new coordinates can be calculated by following circle equations

$$(x - 0)^2) + (y - Hg)^2 = R^2$$

1	current	R2 for +765k\	R2 For-765kV
2	10kA	59.66	43.136
3	15kA	71.622	56.6
4	20kA	82.562	68.562
5	25kA	92.758	79.502
6	30kA	102.35	89.698
7	35kA	111.51	99.312
8	40kA	120.26	108.45
9	45kA	128.68	117.2
10	50kA	136.81	125.62
11	55kA	144.68	133.75
12	60kA	152.32	141.62
13	65kA	159.76	149.26
14	70kA	167.02	156.7
15	75kA	174.11	163.96
16	80kA	181.05	171.05
17	85kA	187.84	177.89
18	90kA	194.51	184.78
19	95kA	201.05	191.45
20	100kA		197.99

Table 3: calculation table for new striking distance

$$(x - \Delta tan(\Theta))^2) + (y - Hp)^2 = R_1^2$$

but numerically there will be very less difference between new striking distance and old striking distance so variation because of self-potential of 765kV line can be neglected.

IX. CONCLUSION

In this report I have done many analyses for various model of overhead transmission lines IEEE model, Height dependent model, height independent model for constant heights, different heights along with different shielding angle that would give better approximation values which will be best suited for construction of certain typical overhead transmission line structure. Further calculation gives best necessary data for construction of the line and because of construction work certain kind of transmission line can be protected against lightening strokes leader at certain high level and will be beneficial for saving nations. The study was achieved on double circuit real line 220kV/400kv and 765 kV line. The results indicated in this work show that the lightning current amplitude, front time and the tower shielding angle must be considered in lightning protection studies. The major part of the surge current was dissipated through the ground. Moreover, the improvement of the transmission lines performances does not ensure alone a complete protection and secondary protections are then essential. The more our life depends on electric power, communication, and electronic systems, the more frequent threat of lightning hazards will become. Accordingly, frequent threat of lightning hazards will become. Consequence would be. The conventional passive lightning protection methods couldn't completely fit for the demand at present. It's necessary to research and apply the Active Lightning Protection technologies to important industries and critical fields.

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