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66kV & 220kV Substation Protection From Lightning by Fixed Angle, Rolling Sphere and Early Streamer Method

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Abstract:

Lightning strokes are most effective in electrical engineering. Charge formation in cloud produces the lightning stroke. Substation equipment and auxiliaries also can be get damaged by the lightning strokes. This paper shows some methods to reduce the effect of lightning stroke on the substation. There are conventional and non-conventional methods for this. This paper describes some of that methods briefly.

Keywords –**Direct stroke lightning protection, Rolling Sphere Method by simple rod, Fixed angle method , Early streamer method.**

I INTRODUCTION

Direct stroke on the transmission line or the substation will cause major damage to the substation equipment. The characteristics of this will be depend on range to region.

According to IEEE the stroke happens in two stages, (i) return stroke, (ii) ionization of air encompassing the center and the advancement of stepped leaders. So, to overcome this cause we have to provide protection. The protection is done by providing lightning mast at different intervals & connecting Earth wire tower to tower. The methods which are explained here are **Rolling sphere method by simple rod, Fixed angle method and Early streamer method.**

There are some methods for direct stroke lightning protection on 66kV and 220kV substation .

1) Empirical design method

   This method includes two methods.

   i) Empirical curves

   ii) fixed angles

Fixed angle method is widely used for 66kV voltage level substation.

2) The electrogeometrical method (EGM)

   This method incudes Rolling sphere method.

Meanwhile, for the EGM, the 'Protection zone of a lightning protection system may be defined as the area of space inside which an termination provides protection against a direct stroke by attracting the stroke to itself".[2]

we will also apply Early streamer method.

II ROLLING SPHERE METHOD BY ROD

It is one type of EGM model method. This method builds on basic principal and theories of Whitehead. An imaginary sphere of radius S rolls over the surface of substation which rolls up on the LM, LCLM, earth wire and shield wire which provides lightning shielding.

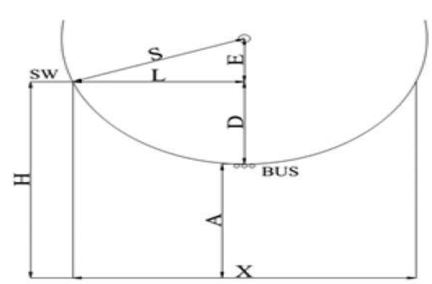

Fig-1: protected area of shield wires at equal height

The equipment is below the curved surface of sphere then said to be protected and the portion which remains

unprotected is remains below the curved surface. Twin moose conductor is used over here.
Now we apply this method on substation having 220kV voltage, calculation is shown below,

Calculation of one section is shown.

For finding the equivalent radius

$$R_c x \ln\{(2 x h)/ R_c\} - (V_c / E_0) = 0$$

Where,
h = height of tower from GL
E_o= Limiting corona
V_c = Rated lightening impulse withstand voltage Gradient

By solving this equation

$$R_c = 0.121 \text{ m}$$

In the case of twin conductor the radius is given by,

$$R_0 = (r x l)^{0.5}$$

So, R_0 = 0.0235 m

Now the radius of corona is in case of twin conductor,

$$R'_c = R_0 + R_c$$

So, R'_c= 0.145 m

The surge impedance if corona is ,

$$Z_c = 60 x \{ \ln (((2 x h) / R'_c) x ((2 x h) / r))\}^{0.5}$$

Where,
r = Radious of conductor (in m)

So, Z_c= 238.168 m

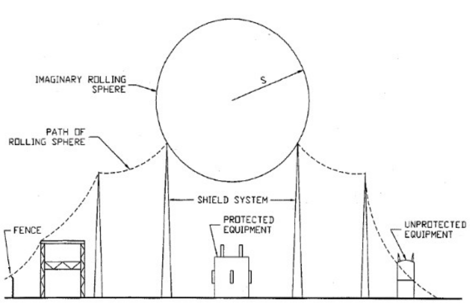

Fig-2: principal of rolling sphere [1]

The allowable stroke current is

$$I_s = (2.2 x BIL)/ Z_c$$

Where,
BIL = Rated lightening impulse withstand voltage (For 220kV BIL is 1050 kV/m & For 66kV BIL is 450 kV/m)

$$I_s = 9.699 \text{ kA}$$

Now, the allowable strike distance is….

$$S = 8 x k x I_s$$

Where,
k = Strikes on shield wire (value for mast is 1.2 & for earthig wire is 1)

$$S = 29.898 \text{ m}$$

H = Height of equipment is

$$H = 12.495\text{m}$$

A = Height of object to be protected

$$A = 20.00\text{m}$$

D = Elevation difference between Height of equipment & Object to be Protected

$$D = 7.500\text{m}$$

E = Elevation Difference between Origin of the rolling sphere & equipment

$$E = 22.398\text{m}$$

L = Horizontal difference between Origin of the rolling sphere & equipment

$$L = 19.804\text{m}$$

X = Maximum allowable Horizontal separation of the shield wires ensuring protection of object at height A

$$X = 39.609\text{m}$$

Here the value of X has not to be more than the diameter the imaginary sphere(S).

Same calculations can be done for the remaining sections of the sub-station.

In this method of protection we have used earth wire and 3No's lightning masts. Under green curve the whole portion is protected by the masts and earth wires.

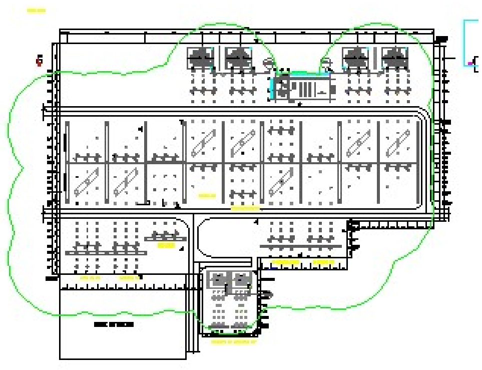

Fig-3: protected layout of 220kV rolling sphere by simple rod

III FIXED ANGLE METHOD

This method comes in the empirical design method. This method was mainly used by designers as a easy boundary of protection against stroke.

The fixed-angle design method uses parallel angles to determine the number, position, and height of shielding wires or LM. Figure illustrates the method for shielding wires.[1]

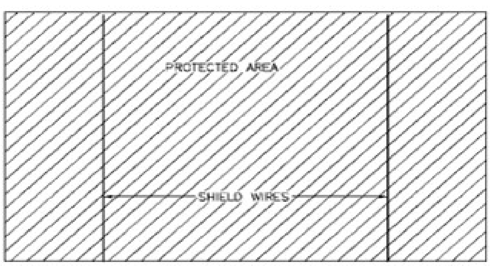

Fig-4: fixed angle method for shielding wire [1]

Area protected by fixed angle method is shown by cross lines.

The layout of 66kv substation is shown here in which we used 1 Lightning Mast and earth wire tower on pick of tower.

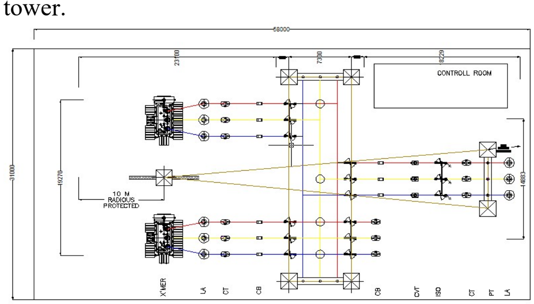

Fig-5: layout of 66kV substation

Now equations for solving this problem is shown here,

For earth wire , measure the height of tower (in m) and the height of equipment (in m), then H the difference between them (in m) is calculated for inner side and outer side radius of protection is R_x..

To reduce shielding angles designers uses fixed angle method as the structure height increases to maintain a low failure rate.

For inner side the degree of protection is 45°(α) and for outer side 60°(β). The equation is,

$$\tan\theta = \frac{Rx}{H}$$

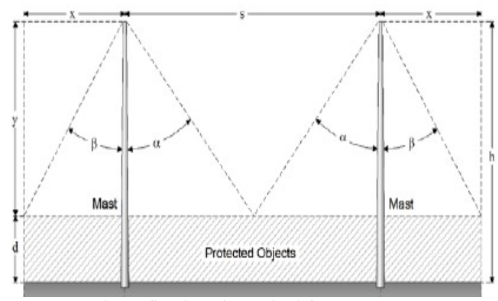

Fig-6: fixed angle method for masts [1]

For lightning mast the degree of protection is always 45°.

$$\tan 45^0 = \frac{Rx}{H}$$

So, the solution is above design is calculated and the protected layout is,

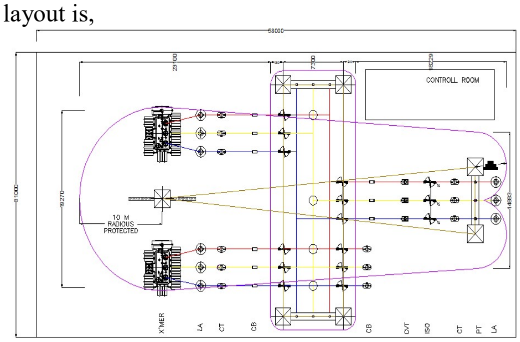

Fig-7: protected layout of 66kV substation

Where the purple line shows the area protected by this method. But the limitation of this method is that it can be suitable only for 66kV or below 66kV substation above 66kv it will not reliable so, by rolling sphere method we have calculate the 220kv substation layout by rolling sphere method by simple rod.

IV EARLY STREAMER METHOD

This is not method but it is one type of equipment which is place over a simple lightning rod which is called as early streamer emission air terminal (OPR).

The OPR efficiency (ΔT):

Lightning is one of the most spectacular meteorological phenomena. Generated by the interaction of clouds elements (water and ice), it can kill, injure and damage. The unique efficiency of the OPR Early streamer emission is based on the difference (ΔT), measured in a laboratory, in between the emission time of the OPR and the one from a simple rod. The OPR ESE air terminal is composed of a striking point connected to a down conductor to conduct the lightning to the ground.

Complete autonomy:

During a storm the ambient electric field may rise from 600 V to 10-20 kV/m. When the electric field reach this level representing a minimum risk for a lightning, the OPR begins to get activated and generates high voltage pulses, helping to create and propagating an upward leader.

After a strike on the OPR, the lightning current is driven to ground by the down conductor to the earth termination system.

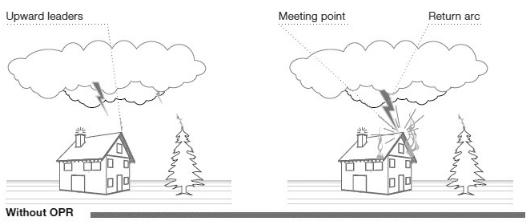

Fig 8-without using OPR

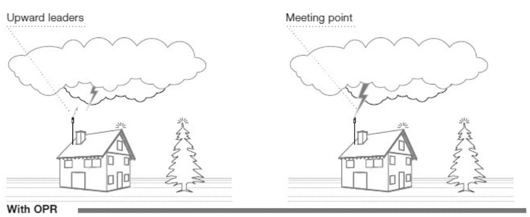

Fig-9: using OPR

Radius of protection:

The radius of protection (Rp) of the OPR is calculated according to the NF C 17-102 (edition 2011). It depends on the OPR efficiency (ΔT) expressed in micro-seconds. The maximum value for ΔT is 60 µs. The risk assessment shall be calculated according to the NF C 17-102. IEC 62305-2 and will define the protection level (LPL I, II, III or IV) which will be used in the determination of the OPR radius of protection.

Now,

Rp(h) : Protection radius at a given height (h)

$Rp(h) = \sqrt{2rh - h2 + \Delta(2r + \Delta)}$ (for $h \geq 5$ m)   For $h < 5$ m, refer to the table below

h : Height of the OPR tip above the surface(s) to be protected

r(m) : Standardized striking distance

$\Delta(m) = 106 .\Delta T$ (OPR efficiency)

According to the customers demand this can be designed but the cost of this equipment is too much high but the surety of the protection is also too much high as the cost and the plus point of this is the number of this will be so less as compared to simple lightning rod.

TABLE -1 OPR radius Protection Table

Protection level	I(r = 20m)		
OPR	30	45	60
h(m)	**Radius of Protection Rp (m)**		
2	19	25	31
3	29	38	47
4	38	51	63
5	48	63	79
6	48	63	79
8	49	64	79
10	49	64	79
15	50	65	80
20	50	65	**80**
45	43	65	76
50	40	65	74
55	36	65	72
60	30	65	69

By this table first we have to choose protection level then OPR then height of OPR and according to that we have to choose OPR which will give the radius of protection by the OPR over the substation.

Here, we have taken protection level I(r = 20m), OPR 60 and Height of OPR is 20m.

So the radius of protection will be 80m. This same height can also be calculated by the equation which is mentioned above.

V CONCLUSION

This paper study the DSLP scheme for 66 & 220 kV substation.

Form we conclude as follows,

1) Fixed angle method is only suitable for 66kV substation; for above 66kV we have to apply EGM method and early streamer method.
2) By applying advanced method of protection total cost of substation will become less

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REFERENCES

[1] IEEE 998-2012 Guide for Direct Lightning Stroke Shielding of Substations.

[2] Comparative Study on Substation Shielding Due to Direct Lightning Strokes, By Ab Halim Abu Bakar Date of publish – December 2013 Email: a.halim@um.edu.my

[3] Lightning Protection Systems Design for Substations by Using Masts and Matlab, By Le Viet Dung and K. Petcharaks.

[4] Understanding direct lightning stroke shielding of substations, By P. K. Sen.

[5] AIEE Committee Report, "A Method of Estimating Lightning Performance of Transmission Lines," AIEE Transactions, vol. 69, no.2, pp. 1187–1196, Jan. 1950.

[6] Anderson, J. G., "Monte Carlo Computer Calculation of Transmission-Line Lightning Performance," AIEE Transactions, vol. 80, no. 3, pp. 414–420, Aug. 1961.

[7] Anderson, R. B., and A. J. Eriksson, "Lightning Parameters for Engineering Application," Electra, no. 69, pp. 65–102, Mar. 1980.

[8] Eriksson, A. J., "The Lightning Round Flash—an Engineering Study," PhD thesis, University of Natal, Pretoria, South Africa, Dec. 1979.