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Various Cases and Studies of Direct Stroke Lightning Protection on Different Substation

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Abstract **-In electrical network lightning of the strokes is most effective fault on transmission line. Lightning occurs due to change formation in clouds and on the surface of earth. Direct stroke on the line can damage substation equipments as well as by network. In this paper we shall design substation to reduce direct strokes by different methods. There are various methods, the classical empirical method and the electro geometric model and non-conventional lightning terminals method. In this paper we study different methods of protection applying to the substations.**

Keywords—DSLP, Fixed angle method, Rolling sphere method, Rezavig method.

INTRODUCTION

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

According to IEEE standard [1] the stroke happens in two stages, (i) ionization of air encompassing the center and the advancement of stepped leaders, (ii) return stroke. So, to overcome this cause by the stroke we have to provide protection. The protection is either done by connecting Earth wire tower to tower or by providing lightning mast at different intervals. The methods which are explained here are fixed angle method, rolling sphere method and razevig method.

There are two methods which can be used for direct stroke lightning protection for switch yard.

1) Empirical design method
   This method includes two methods.
   i) fixed angles
   ii) Empirical curves

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

2) The electrogeometrical method (EGM)
   This method incudes three methods.
   i) Mousa's EGM
   ii) Eriksson's EGM
   iii) Rolling sphere

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

We will also apply Razevig method which he one, two, three lightning mast methods.

FIXED ANGLE METHOD

This method comes under the empirical design method. This method were originally used by designers as a convenient boundary of protection against lightning stroke.

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

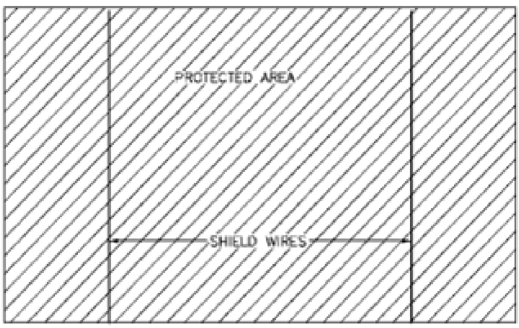

Fig-1: fixed angle method for shielding wire [1]

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The cross lines shows the protected area by fixed angle method by to shield wires.

The layout of 66kv substation is shown here in which we used one LM and earth wire tower to tower pick.

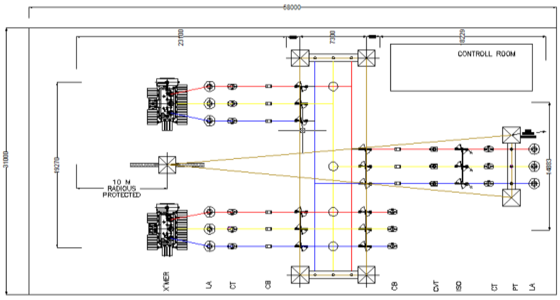

Fig-2: layout of 66kV substation

Now equations for solving this problem is shown here,

For earth wire we have to 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 both inner side and outer side radius of protection is R_x..

The designers uses fixed angle method to reduce shielding angles 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,

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

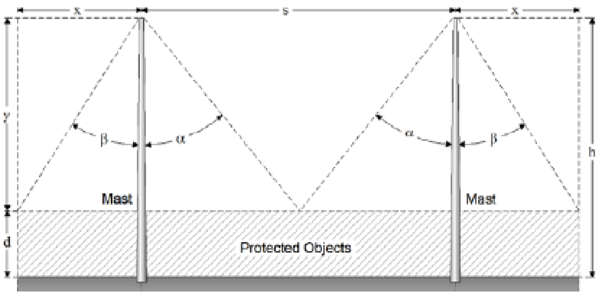

Fig-3: fixed angle method for masts [1]

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,

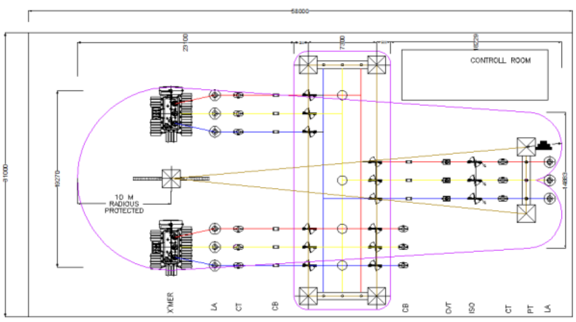

Fig-4: protected layout of 66kV substation

Where the purple line shows the area which is protected by this method. But the limitation of this method is that it can be reliable only for 66kV or below 66kV substation above 66kv it will not reliable so, th1e method named rolling sphere by which we calculate the 220kv substation layout by rolling sphere method.

ROLLING SPHERE METHOD

It is one type of electrogeomatric model method. This method builds on basic principal and theories of Whitehead. This method uses an imaginary sphere of radius S over the surface of substation which rolls up on the lightning mast, earth wire, shield wire and fences which provides lightning shielding.

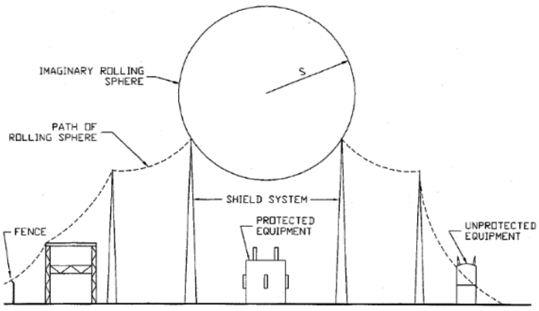

Fig-5: principal of rolling sphere [1]

The equipment is said to be protected if it remains below the curved surface of sphere and the portion which is to cut by that sphere remains unprotected. We have used twin moose conductor here.

Now we apply this method on 220kV substation whose calculation is shown below,

Calculation of one section is shown below.

For finding the equivalent radius

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

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

By solving this equation

$$R_c = 0.125 \text{ m}$$

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

$$R_0 = (r \times l)^{0.5}$$

So, $R_0 = 0.024$ m

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

$$R'_c = R_0 + R_c$$

So, $R'_c = 0.149$ m

The surge impedance if corona is ,

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

Where,
r = Radious of conductor (in m)

So, Zc = 236.632 m

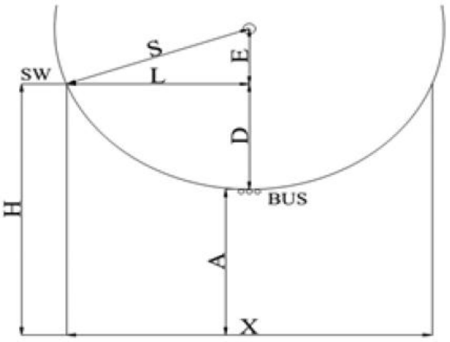

Fig-6: protected area of shield wires at equal height

The allowable stroke current is

$$I_s = (2.2 \times BIL) / Z_c$$

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

$$I_s = 9.7 \text{ kA}$$

Now, the allowable strike distance is….

$$S = 8 \times k \times I_s$$

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

$$S = 25.007\text{m}$$

H = Height of equipment is

$$H = 12.50\text{m}$$

A = Height of object to be protected

$$A = 18.00\text{m}$$

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

$$D = 5.500\text{m}$$

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

$$E = 19.507\text{m}$$

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

$$L = 15.647\text{m}$$

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

$$X = 31.294\text{m}$$

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

In this method of protection we have used three lightning masts and earth wire. Under green curve the whole portion is protected by the masts and earth wires.

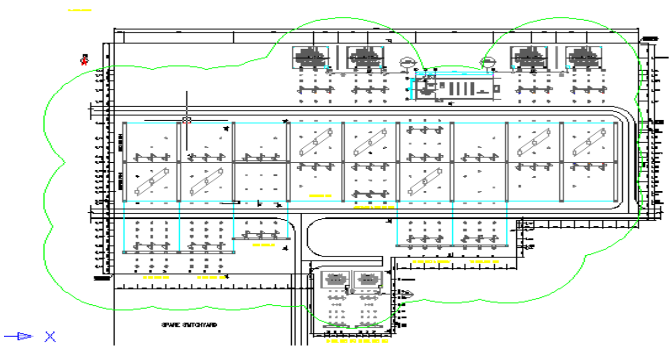

Fig-7: protected layout of 220kV rolling sphere

Eriksson's improved EGM took a more physical approach than the simple EGM by taking into account the dependence of striking distance on the structure height in addition to the known dependence on peak stroke current shown in Table 1 below per IEC 62305-1 (2006). [8]

Table-1 [8]

LPL	Leader charge Q (c)	Peak Current I_p (kA)	Striking distance (m)	% striking distance > I_p
I	0.16	2.9	20	99
II	0.38	5.4	30	97
III	0.93	10.1	45	91
IV	1.80	15.7	60	84

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RAZEVIG METHOD

In the electrical installation the lightning conductor in the form of lightning mast (L.M.) and earth wire are used for direct stroke lightning protection. In this method we have to calculate the area protected by the LM and earth wire. In this the protection by LM is done by one, two, three, four no's of LM. For LM internal and external protective zones are there & the calculation of earth wire is simple. This method is pretty much similar as rolling sphere method.

The height of LM above ground level (h) and the height of equipment to be protected (h_x) is calculated.

The plan for 220kV substation is remains same.

Calculation for single lightning mast is shown below,

$R_x = 1.5*h*(1-(h_x/(0.8*h)))$ For $h_x \leq 2/3$ h

$R_x = 0.75*h*(1-(hx/h))$ For $h_x \geq 2/3$ h

Where,
h_x = Maximum height of live conductor to be protected
h = Height of ground wire

By solving this equation we get the value of R_x.

For three LM,

Consider the LMs 1, 2, 3 with h height (m) located as shown in the enclosed drawing at the corners of triangle. For the area covered by the circle passing through the corners of which the LMs are situated is not greater than 8 time to the active height of the lightening mast.

The diameter D of the circle passing through the tip of the LMs is

$$D < 8(h-h_x)\ \rho$$

Then the area under cover this circle protect as per condition stated.

For the calculation of earth wire we have to calculate the horizontal separation between two ground wires (S).

Now for protection the condition is S = 4h.

If S is less the 4h then the entire area below the curve is protected & if more then it will not cover the area.

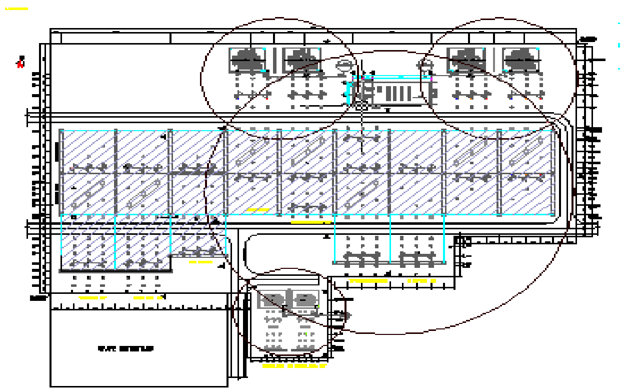

Fig-8: protected layout of 220kV razevig method

CONCLUSION

This paper study the direct stroke lighting protection scheme for 66 & 220 kV substation.

Form we conclude as follows,

1) Fixed angle method is only economic for 66kV substation; for above 66kV we have to apply EGM method or Razevig method.
2) Total cost of substation will become less by applying advanced method of protection.

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