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DESIGN AND ANALYSIS OF LIGHTNING PROTECTION FOR SUBSTATIONS

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The study of natural disturbance lighting and protection against is very important in protection of substation. For designing and analysis of lightning protection of substations, a computer program has been developed with the help of Matlab in graphical user interface (GUI). Shield wire scheme has been implemented for lightning protection. Economical criterion has been given the major preference in this computer application while maintaining the protection. This computer application Matlab tool can quickly design lightning protection for Substation and it may prove to be very helpful for design engineers in the field. In this paper methodology and inputs/outputs of the developed program tool is presented. This study also shows an example of local Rohri substation with results and developed program tool proved to be useful as discussed in conclusion.

Keywords: Computer, Substation, Protection, Lightning, Shield wire.

1. Introduction

Lightning may cause failure of whole substation for example lightning flashovers and damage to substation equipments as in [1,2] because of its unpredictable and probabilistic nature [3]. Lightning protection scheme for substations is essential for the minimization of lightning strokes to equipment and buses [3]. With respect to one estimation/working done by ABB, Substation cost varies from $1.8 million to $5.5 million and if we consider per KW cost then it will be from $36 per KW to $110 per KW [4]. As far as system continuity and reliability is concerned for demand side customers, this amount presents a huge finance in comparison with lightning protection cost.

There are three different lightning protection schemes with the help of which lightning protection can be achieved: by using shield wires, earth masts, and shielding wires and earth masts both [3]. The most important point here is that using earth masts present more cost as it involves construction of foundation and spare gantry for this scheme [5]. On the other hand, shielding wires present alternative paths for the lightning current to ground instead of only one dedicated path as in case of earthing masts. Hence, shielding wires are much preferred than earthing masts regarding reliability and economically.

In addition, the Substation selected for this research work for lightning protection is a 220kV Rohri Air Insulated Substation. This work has been completed using Love, Mousa, Srivastara, Gilman and Whitehead equations [3]. However, Mousa and Srivastara (rolling sphere method) equations were applied for this work as there is no need of modifications in comparison to others for implication of equations.

The most important point need to be considered here is that how to achieve lightning protection for the Substation with the help of shielding wires within a short time interval. To cater the problem, this paper describes a computer application tool program for designing of a lightning protection system scheme using shielding wires for Substations. This computer application tool has been developed with the help of Matlab. On the other hand, a lightning protection systems scheme designed should have the minimum length of shield wire resultantly the economic cost should be achieved, as a principal objective [3]. Hence, this paper describes the computer application program to achieve the objective using shield wires.

In the coming sections, methodology, Simulation Results and Conclusions will be discussed in detail. In methodology section, the method will be discussed upon which the lightning calculation has been performed. Also, the calculations regarding the lightning stroke current and striking distance has been performed. This study included an example of local Rohri substation. In simulation results section, with the help of graphical user interface in Matlab the computer application tool has been developed for the lightning protection design of a Substation using shield wires. Inputs / Outputs of the developed computer program tool have been

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presented step by step and the same has been elaborated in this section with the help of figures. Lastly, conclusion has been given in the light of simulation results obtained.

2. Methodology

Striking distance is the key important factor for designing a lightning protection for a Substation using shield wires [6]. There are different methods for the implementation of the lightning protection scheme namely: fixed angle method, empirical curves and rolling sphere method [7]. However, rolling sphere method has been applied for this work as there is no need of modifications in comparison to others for implication of equations [3].

In a substation, gantries are normally placed at their position and shield wires have to be placed at these already placed gantries to provide lightning protection to the under cited placed equipment, there is no need of construction of foundation/placement of gantries for the shield wires [5]. For an equipment to be protected, its height should be within a range between the height of shield wire and zero ground level. The desired objective in this case is that the placement and location of the shield wires are in such a way that should produce a protection zone to protect all the equipment located in a air insulated substation [8]. In short, protected zone produced by minimum usage of shield wire should cover/protect all the located equipments in the Substation.

The important parameter which needs to be considered for the calculation of protection zone is primarily the striking distance which further depends on many different parameters namely: height of shield wire, basic lightning impulse insulation level, radius of busbar conductor used, height of conductor and the most important the striking current [7]. As stated earlier, revised electrogeometric model for rolling sphere method [8] has been applied with following equations:-

$$Is = \frac{2.2*(BIL)}{Zs} \tag{1}$$

where 'Is' is the lightning stroke current in kA, BIL is the basic insulation lightning impulse level in kV and Zs is the surge impedance in ohm [3]. The strike distance can be found from the following:-

$$S = 26.25*k*I^{0.65} \tag{2}$$

where S is the striking distance in feets, k is the coefficient accounting for a different strike distances for the present work as per IEEE 998-96 this value comes out to be 1 [3] and I is the lightning stroke current in kA.

For a 220/132kV Rohri Substation, on the 220kV side, BIL level, height of busbar conductor used, distance between conductor and radius of conductor equals 1050kV, 18.5m, 0.4m and 0.016m respectively. After putting these parameters in equations (1) and (2), strike distance for the 220kV side of Rohri Grid Station comes out to be 27.8534m. On the 132kV side, BIL level, height of busbar conductor used and radius of conductor equals 650kV, 13.8m and 0.08m respectively. After putting these parameters in equations (1) and (2), strike distance for the 132kV side of Rohri Grid Station comes out to be 20.7342m.

Hence, protective zones should be in such a way that they should cover all of the equipment placed in a Substation. This computer application tool works on the principle that there should be minimal overlap region between the protection zones of the adjacent shield wires. Also as in [3], economical measure is the ultimate objective of the design Engineers i.e the material should be used as minimum as possible with achievement of design characteristics. In this work, to achieve the economic objective, the length of shield wires used for the lightning protection scheme designing should be as small as possible with protection zones cover the whole of the Substation keeping the overlapped region between the adjacent shield wires should be as minimum as possible. Hence, this computer application tool keeps the overlapping of protection zones minimum and gives the minimum total length of shield wires.

3. Flow Chart Presentation of Methodology

The adopted flow chart for analyzing the lightning protection of a substation is given below:

Step – 1: Input the data

Step – 2: Outer Boundary Of Substation

Step – 3: Laying Equipment Of Substation

Step – 4: Laying Gantries Of Substation

Step – 5: Laying Shield Wire Conventionally

Step – 6: Calculation of 'S' For 132kV & 220kV

Step – 7: Projecting 'S' in a Substation

Step – 8: Shield wire length & Overlapped Area Calculation

Step – 9: Laying Equipment & Gantry in Substation

Step – 10: Laying Equipment & Gantry in Substation

Step – 11: Laying Shield Wire IEEE method

Step – 12: Calculation & Projection of 'S' for 132kV & 220kV

Step – 13: Shield wire length & Overlapped Area Calculation

The above flow chart shows the steps which will be adopted in simulation results for getting upto the conclusions.

4. Simulation and Results

With the help of graphical user interface of Matlab, this computer application tool has been developed for the lightning protection design of a Substation using shield wires. To understand the use of computer application Matlab tool, following graphical user interface has been developed:

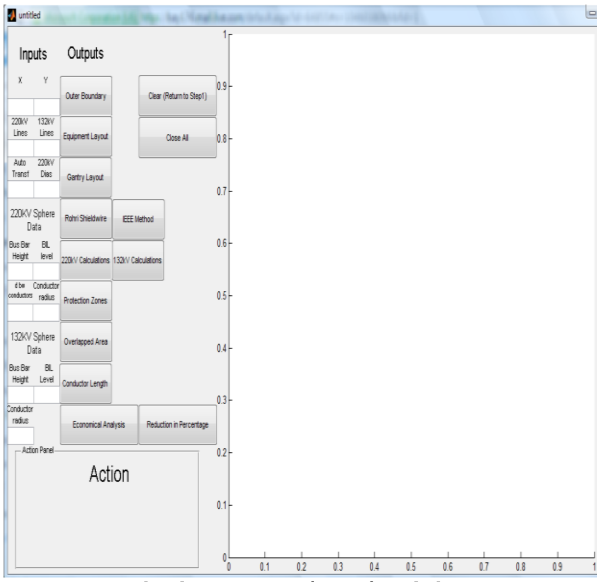

Figure 1. Graphical user interface for lightning protection application.

For the usage of this computer application tool, we have considered a substation with following information;

1. The dimension of the substation is 201.35x243.5m^2.
2. There are 4 Nos. 220kV lines, 4 Nos. 132kV lines, and 2 Nos. Transformers.
3. On the 220kV side, for strike distance calculations we have BIL level, height of busbar conductor used, distance between conductor and radius of conductor equals 1050kV, 18.5m, 0.4m and 0.016m respectively.
4. On the 132kV side, for strike distance calculations we have BIL level, height of busbar conductor used and radius of conductor equals 650kV, 13.8m and 0.08m respectively.

This application has been developed as a step-wise criteria and analysis will be done as shown in the following steps with conventional practice and IEEE method then the comparison between the two practices:

Step 1: Input the opposite faces (x & y), Nos. of 220kV lines, 132kV lines & transformers, BIL level, height of busbar conductor used, distance between conductor and radius of conductor as shown in following Figure 2.

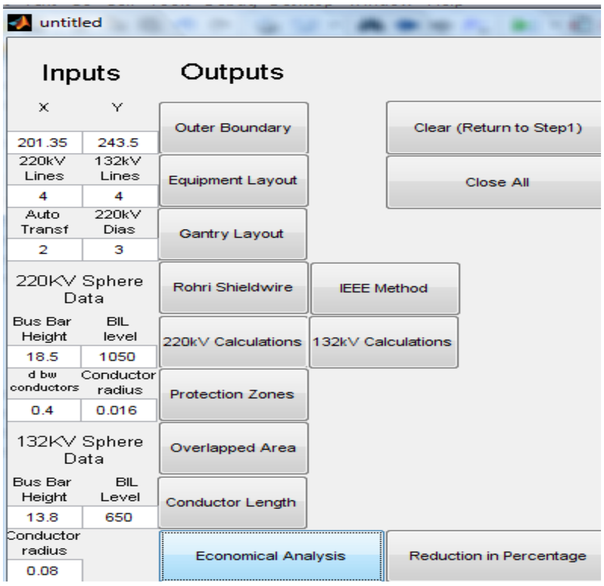

Figure 2. Inputs for the lightning protection of a 220kV Rohri substation.

Step 2: Outer boundaries of a 220kV Rohri Grid Station with x and y boundaries as 201.35m and 243.5m respectively.

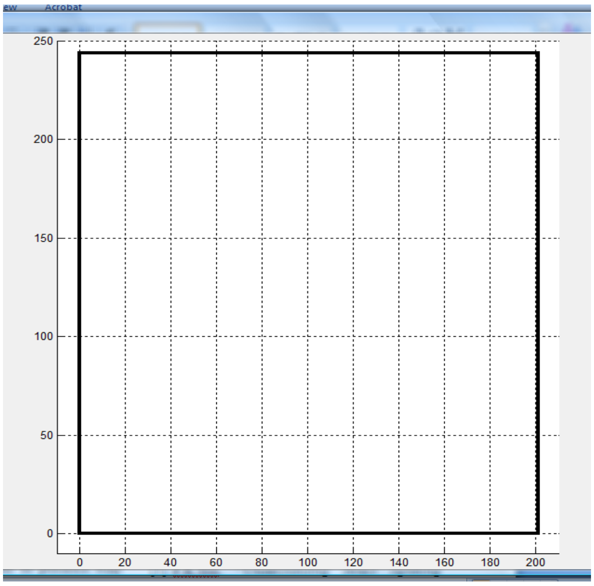

Figure 3. Outer boundaries of 220kV Rohri substation.

Step 3: This step shows the equipment laying procedure for the under discussion substation with 4 Nos. 220kV line bays, 4 Nos. 132kV line bays, 2 Nos. 220/132kV trafo bays, 1 No. auxiliary transformer, 1 No. coupler bay and 1 No. PT bay.

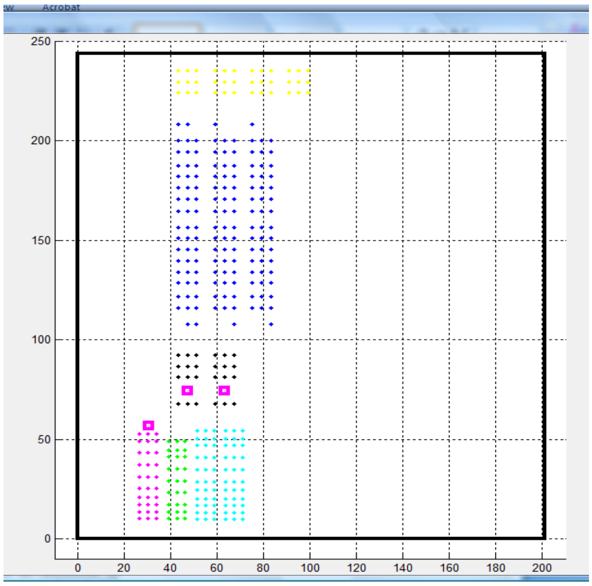

Figure 4. Equipment layout of 220kV Rohri substation.

Step 4: This step will place the gantries in a substation according to the Nos. of 220kV and 132kV lines.

Step 5: According to conventional practice, shield wires have been placed in a substation without any IEEE calculations and economical considerations as shown below in Figure 6.

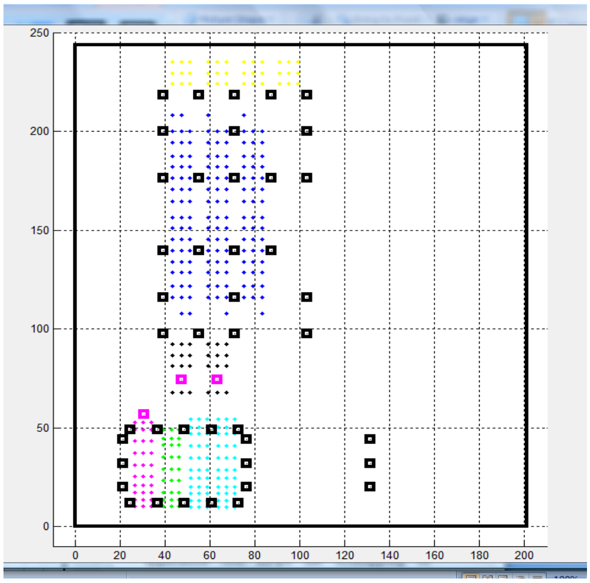

Figure 5. Laying Gantries of 220kV Rohri substation.

Step 6: Strike distances has been calculated in this step for projecting protection zones in a substation for 220kV and 132kV both and they come out to be 27.8354m and 20.7342m respectively.

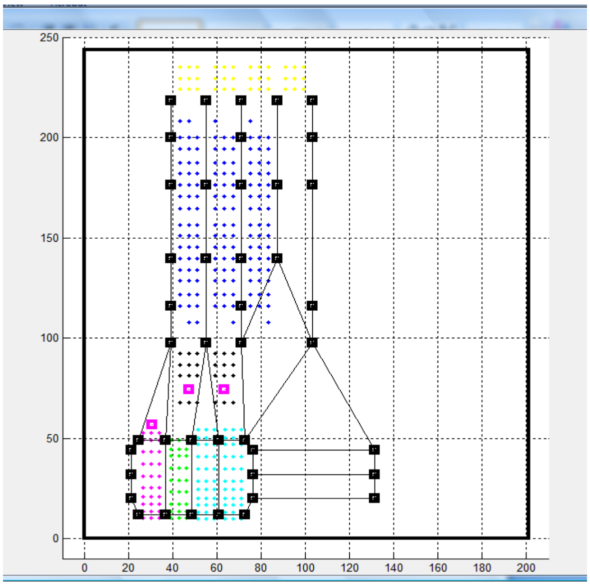

Figure 6. Laying Shield wires of 220kV Rohri Substation according to conventional practice.

Step 7: Strike distances found in step 6 has been projected as shown in the following Figure 7.

Step 8: This step calculates the Overlapped area between the protection zones and length of shield wires used. The required parameters come out to be 110462m and 1490mrespectively.

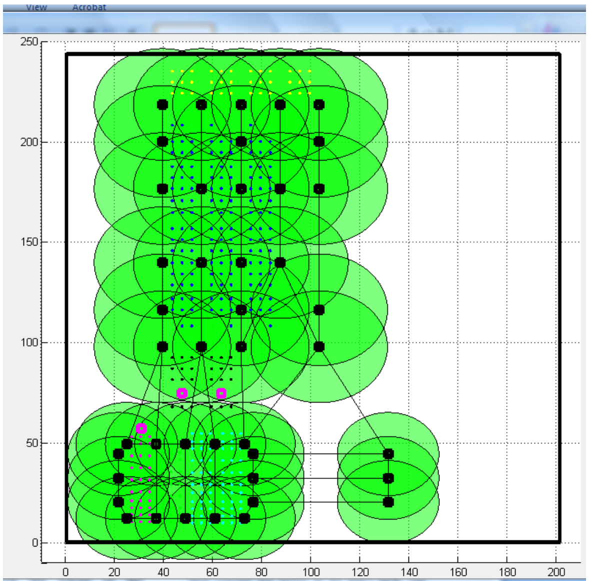

Figure 7. Protection zones for 220kV Rohri substation.

Step 9: The conventional practice for laying of shield wires has been done. Now, IEEE practice will be done by returning to equipment and gantry layout step.

Step 10:Our prime objective for the lightning protection designing of a substation is that shield wires should be lay economically in such a way to cover whole of the substation with no equipment out of the protection zones and the overlapped area between the protection zones should be minimum. The IEEE method for laying of shield wires with economical length of shield wire has been done as shown in the following Figure 8.

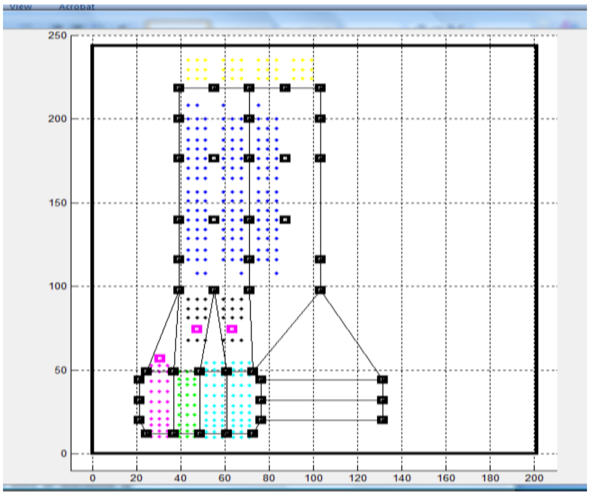

Figure 8. Laying Shield wires of 220kV Rohri Substation according to IEEE practice.

Step 11: Then againStrike distances has been calculated in this step for projecting protection zones in a substation for 220kV and 132kV both and they come

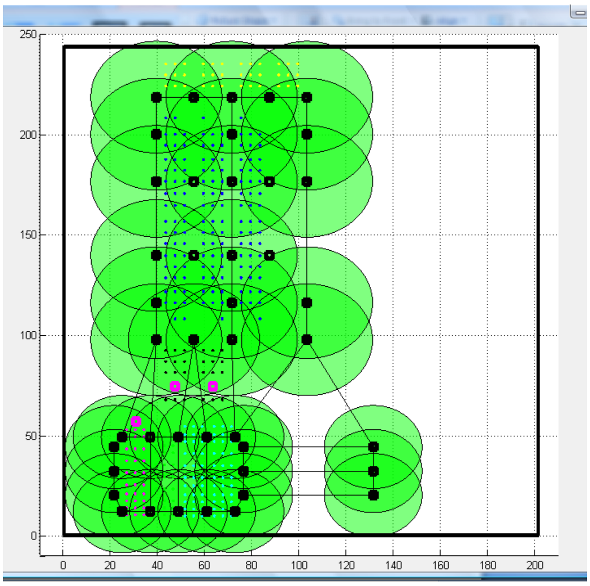

Figure 9. Protection zones for 220kV Rohri Substation with respect to IEEE method.

out to be 27.8354m and 20.7342m respectively with protection zones as shown below.

Step 12: This step again calculates the Overlapped area between the protection zones and the total length of shield wires used after incorporation of IEEE method. The required parameters come out to be 61200.1 m and 1264 m respectively.

5. Results and Discussion

Lastly, this computer application tool will analyze the lightning protection design economically and also the percentage analysis has been done to show that for how much amount shield wire reduction has been achieved. For the present case, this tool has shown a message "Rohri Grid Station Lightning Protection is over designed" and percentage analysis has calculated a reduction in shield wire of 17.872% by adopting IEEE method.

6. Conclusion

The program has also been developed for designing of lightning protection in a substation by using masts [9]. In the same way, computer software tool has been developed for lightning protection zones in a grid station using visual basic language [10]. In comparison with the said work [9 & 10], this computer application tool has been developed for designing of a lightning protection using Matlab as well as with the real existed Grid Station data. The most important feature of this program is that using IEEE method, lightning protection designing with the help of a shield wires in a grid station can be done for any area.

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