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Comparison of AIS and GIS based on grounding design- A review

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ABSTRACT

In any substation, grounding system deserves considerable attention as far as performance and design are considered. So grounding play very important role in the operation of the power system. The main purpose of this work is to design the grounding system for 400kV Darbhanga GIS substation. Then after the grounding design is done for identical 400kV AIS substation and comparison made between both types of the substation for grounding design. This design is done by using the IEEE 80-2000 standard for the safe grounding design in AC substation. Also, the comparison also made for both type of substation that how they differ from each other like the space requirement, spacing, no of equipment for both types of the substation, etc. The Auto Grid Pro and SD calc software are used for the grounding design of both types of the substation.

Keywords: *Grounding grid, Step voltage, Touch voltage, Grid resistance, Ground grid design, Ground potential rise (GPR), Ground rod, resistivity, Split factor, Reflection factor (K).*

1. INTRODUCTION

The main part of the power system is Generation, Transmission, and Distribution. For this, power system has passed through different types of the substation. In any safe and reliable substation, a well-designed grounding system plays a crucial role. The absence of safe and effective grounding system can result in mal-operation of control and protective devices which disturb the operation of complete power system. Hence great care should be taken while designing grounding system of any substation, primarily to ensure electrical safety of persons working within or near substations.

Main two functions of any grounding system are :

1) To provide a path for electrical current to earth without exceeding operating limits of equipments.

2) To provide a safe environment for protecting personnel in the vicinity of grounded facilities from the danger of electrical shock particularly under fault conditions.

Grounding system has all the interconnected grounding facilities in the switchyard area which include ground grid, overhead ground wires, and neutral conductors underground cables etc. ground grid being the main component. The ground grid consists of horizontal interconnected conductors often supplemented by vertical ground rods. Being major component of the overall grounding system, the design of grounding grid should be such that total grounding system is safe and at the same time it is cost –effective.

In recent years, a SF6 gas-insulated switchgear (GIS) indoor substation is adopted by power utilities, particularly the power utility supplies electric power to the urban area. This is because GIS indoor substation can reduce an environment impact, and also increase safety for people and operation and increase reliability. Due to the very high cost of land, it is extremely difficult to acquire a large piece of land for constructing the conventional air-insulated outdoor substation (AIS) in an urban area.

The design of grounding system for GIS indoor substation is different from conventional AIS. GIS indoor substation normally occupies only 10-25% of the land required for conventional AIS. Therefore, the grounded area of GIS indoor substation is also reduced. Also, the grounding system of the building in GIS indoor substation has to be taken into account, especially the working area of technicians and operators. Here the design of grounding system for GIS indoor substation and AIS outdoor substation is according to IEEE Std. 80-2000.Other considerations of grounding system in GIS building to meet safe grounding design are described.

AutoGrid Pro is very powerful, and very easy tool for carrying out grounding studies which provide a simple, automated and integrated environment for use. The software package consists several integrated engineering modules which are designed to study the effectiveness of grounding installations with respect to the electrical safety of both personnel and equipment, allowing you to suggest improvements to existing or new installations. A wide variety of soil structures also be implemented by AutoGrid Pro and can determine the soil structure from field resistivity measurements. The program can model grounding grids of any shape and size and several electrodes can be modeled simultaneously. The fault current distribution between the grounding system and other metallic paths such as overhead ground wires, shield wires, neutral conductors, and armors can also be implemented by this software.

2. AIS AND GIS

An electric power substation that has the busbars and equipment terminations generally open to air and utilizes insulation properties of ambient air for insulation to the ground is called air insulated sub-station (AIS).

In Gas Insulated Switchgear (GIS), the equipment is is installed in a metal enclosure with a pressurized gaseous, dielectric medium (SF6). This gas has a higher insulating value than air, allowing a more compact design compared to the air insulated high voltage substations [11]

Air insulated substations stand out due to low investment costs, but on the other hand, they are more susceptible to outer disturbances which affect the maintenance and operating costs adversely. Gas insulated substations, however, have high investment costs, but have a lower susceptibility to environmental conditions and therewith have lower operating and maintenance costs due to their encapsulated design. In GIS, SF6 acts as an insulation between live parts & the earthed metal closure. The dielectric strength of SF6gas at atmospheric pressure is approximately three times that of air. Space requirement is only 10–25% of what is required is a conventional substation [5]

The environmental model consequently considers SF6 leakage rate of 0.2% per year for AIS and of 0.1% per year for GIS. But because it contains a larger amount of SF6 gas, losses are higher in GIS substation than in AIS one [11]

The AIS Live Tank substation requires a larger amount of electric energy than the GIS sub-station mainly because the AIS bus-bar is much longer than the GIS one resulting in higher resistance losses.[11]

The GIS substation has a lower environmental impact than the AIS substation due to electricity losses four times less important than for AIS substation. However, the GIS solution is more impacting on global warming indicator due to higher quantities of SF6, and on ozone depletion indicator due to higher quantities of Teflon. Environmental impact of GIS is particularly low on ionizing radiation and water depletion indicators where electricity losses are the major contributors. [11]

In AIS, the future expansion can be done easily, while it becomes more difficult in GIS. Also in AIS, fault location can be found easily as all equipment is within the view which is not possible in GIS.

AIS is subjected to direct lightning stock and o other external events such as heavy wind, rains, and cyclones. Also, deposition of particles on insulators can cause insulation failure. While no such problems occur in GIS.

3. ELEMENTS OF GROUNDING GRID

A good grounding system should be able to maintain the actual mesh and step voltages within a substation well below tolerable touch and step voltages respectively. These tolerable safety criteria have been established based on fibrillation discharge limit of body current. There are two methods to ensure that the criterion listed previously is met.

1) Decrease the touch or step voltage the body can be subjected to. This can be achieved by either limiting the grid current or reducing the grid resistance.

2) Decrease the amount of time to clear a ground fault, which can be used by fast tripping of a protective device.

For understanding criteria, following parameters are needed to be considered in grounding design for both AIS and GIS :

1) Ground Potential Rise:

GPR is the maximum electrical potential a grounding grid may attain relative to a distant grounding point assumed to be at the potential of the remote earth. GPR is proportional to both the current flowing in the ground grid and the equivalent grid impedance as shown in the following equation:

$$GPR = I_f * R_{grid} \quad \text{.... (1)}$$

Where, If = total fault current;

Rgrid = ground grid resistance to remote earth

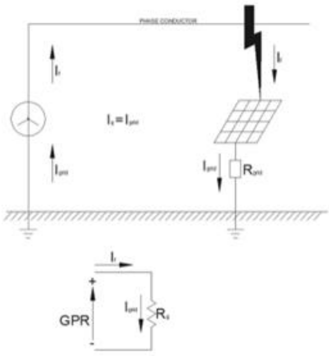


Fig.1

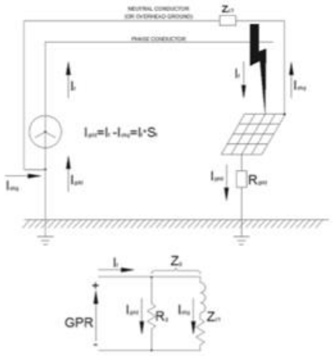


Fig.2

Fig. 1. Grid current is equal to the fault current when no shields or neutrals are present

Fig. 2. Grid current is only a fraction of the fault current when a shield or neutral is present

Equation (1) assumes that the entire fault current is flowing through the ground grid (If = Igrid) to remote earth (Fig. 1). If a substation is supplied from an overhead line with no shield or neutral wire, the total ground fault current enters the earth, causing an often steep rise in the local ground potential. The primary way to limit the GPR in such a case is to create a ground grid that has a very low resistance to remote earth. Limiting the current flowing in the ground grid also lowers the GPR. The use of a shield wire or neutral provides an alternate path for the ground fault current to flow to the source instead of the earth. A split factor is added, as shown in equation (2), to indicate the percentage of the ground fault current assumed flowing into the earth (Fig. 2)

GPR =If ∗Sf ∗Rgrid or

$$GPR = If * Zg \quad (2)$$

where Sf split factor;

Zg total equivalent ground impedance.

2) Step Voltage:

The step voltage is defined as potential difference felt by a living thing having a distance of one feet between his/her feet without having contact with any part of body touching with solidly grounded structure.

The calculation for step voltage for 50kg and 70kg body is given by the following equation:

$$Estep50 = (1000 + 6Cs * \rho s)0.116/\sqrt{ts} \quad (3)$$

$$Estep70 = (1000 + 6Cs * \rho s)0.157/\sqrt{ts} \quad (4)$$

Where Cs is a function of ρs and hs. It is a correction factor for computing the effective foot resistance in the presence of a finite thickness of surface material;

ρs is resistivity of the surface layer in ohm meter;

ts is the duration of the shock current in seconds.

The correction factor Cs is dependent upon the depth and resistivity of the surface material and the resistivity of the soil layer beneath the surface material. Cs provides a correction to the estimated resistance of a human foot in contact with the surface material and is used in both the calculations for allowable step and touch voltages. Cs increases as the surface material thickness increases. However, the effect of the surface material thickness diminishes greatly after approximately 12 in (or 0.3 m).

The higher this value of Cs, the greater is the allowable step potential before the body will absorb a critical amount of shock energy.

Based on (3), the greater the resistivity of the surface layer and the shorter the fault duration, the greater the step voltage must be to have an effect on the human body. Faults can be cleared in very short time periods depending on protective devices and relaying schemes. A fault clearing time of 1 s (a common design practice) is assumed to be on the conservative side. If the time is held constant at 1 s, the greater the surface soil resistivity is, the greater the allowable step voltage can be without causing a hazardous shock.

3) Touch Voltage:

The touch voltage is described as a difference in potential between GPR and potential at the surface where a living thing is standing with his/her hands touching the structure which is connected to a solid ground point.

Allowable touch voltage uses a very similar equation to step voltage and is shown as:

$$Etouch50 = (1000 + 1.5Cs * \rho s)0.116/\sqrt{ts} \quad (5)$$

$$Etouch70 = (1000 + 1.5Cs * \rho s)0.157 / \sqrt{ts} \qquad (6)$$

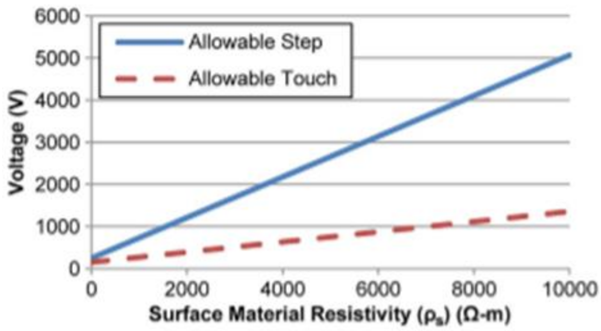


Fig.3

Fig. 3 shows the effects of surface material resistivity on the allowable step and touch voltages for a fault duration of 1 s.

4) Split Factor:

The generally accepted practice, and, in some instances, a requirement of a ground grid, is to have a low impedance to remote earth (less than 1–5 Ω). However, as stated in IEEE Std. 80, "a low substation ground resistance is not, in itself, a guarantee for safety. There is no simple relation between the resistance of the ground system as a whole and the maximum shock current to which a person may be exposed". Even though IEEE Std. 80 states that a low ground resistance is not, in itself, a guarantee of a safe ground grid, somehow it has become a standard practice in determining the acceptability of a ground grid.

In cases where a ground resistivity is high, yielding a high ground grid resistance, the use of overhead neutral or ground wires can help alleviate the amount of fault current flowing through the ground grid.This is defined by the split factor (Sf).

As depicted in Fig. 2, part of the fault current (IE) flows back over the overhead ground wire to the source, thereby reducing the grid current (Igrid) which will limit the step and touch potentials. It should be noted that the ground potential gradient may be higher, requiring additional equipment to isolate communication circuits and other devices that are not rated for the higher voltage levels. Applying the split factor should be used with caution since it is very difficult to calculate the exact value. Various factors including shield wire resistance, number of shield wires, remote substation ground resistance, and pole footing resistance will all influence the amount of current flowing to remote earth and to remote grounding systems.

5) Single-Layer, Two-Layer, and Multilayer Soil Models

Many of the commercially available software utilizes multilayer soil model. Single-layer soil model assumes a generally uniform and homogeneous soil resistivity and is calculated by using the arithmetic average of the measured soil resistivity data. The equation for this model is

$$\{ \rho a(1) + \rho a(2) + \rho a(3) +\bullet\bullet\bullet+ \rho a(n)\}/ n \qquad (7)$$

The single-layer model does not provide good accuracy with large variations in soil resistivity measurements.

The two-layer soil model is represented by an upper layer uniform soil of a finite depth and a lower layer of uniform soil of infinite depth. As a compromise, the two-layer soil model is often used for designing grounding systems. These calculations are often sufficient, while a more accurate multilayer soil model is rarely justifiable or technically feasible.

A multilayer soil model is used when highly non-uniform soil conditions are encountered, requires complex computer programs or graphical methods, and is seldom used in the design.

6) Surface Material

The surface material becomes very important when designing a substation ground grid in the high-resistivity soil. A layer of crushed rock or other material has become the design standard to provide a high resistance between the ground grid and personnel. If the underlying soil has a lower resistivity than the Surface layer, then only a small amount of grid current will flow into the surface layer, resulting in a smaller potential rise in the surface material. Additionally, the resistance between personnel and the ground is increased, reducing the amount of current that may flow through the person to ground.

Fig.3 shows the effects of surface material resistivity on allowable step and touch voltages. Fig. 4 shows the effects of varying surface material depth on allowable step and touch potentials.

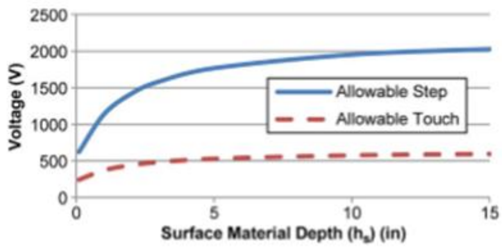


Fig.4

7) Mesh Voltage (Vm):

The mesh voltage is described as a difference in potential between the center of ground grid mesh and structure which is solidly grounded connected to remote earthing electrode buried at a sufficient depth below ground surface.

8) Earth Surface Potential (ESP):

Earth surface potential is defined as the difference in potential between mesh voltage (Vm) and Touch voltage (Vt).In worst case scenario it is observed that mesh voltage is actually touched voltage.

9) Ground Resistance (Rg):

The ground resistance is defined as the resistance of overall ground grid mesh through which the fault current will flow and will be efficiently dissipated to the earth. It is necessary to have the ground resistance kept at a low level for proper dissipation of fault current without having any substantial rise in grid potentials.

10) Fault Current (If):

The value of fault current is defined as the maximum current which flows along the ground grid mesh the designing of ground grid mesh is based on worst condition fault current that may arise in the substation considering all design constraints.

11) Short term temperature rise:

It is defined as a rise in temperature that may occur along ground grid mesh horizontal conductors and vertical rods. It is necessary to properly analyze the temperature rise in order to avoid any arcing which may result in hazardous situation across ground grid mesh.

12) The weight of person (Kg):

It is defined as reference weight of a person on the basis of which all the calculation related to above-mentioned parameters are based upon. The calculation can be done for a person having a body weight of 50kg or 70kg.

4. TECHNIQUES FOR INCREASING GROUND GRID SAFETY

a. Traditional Methods

Traditionally, as it is mentioned before, the aim of ground grid engineers has been to lower the grid resistance, thus minimizing step and touch voltages during a ground fault. This is accomplished by one or more of the following methods:

1) Decreasing ground grid spacing;

2) Installing additional ground rods;

3) Using longer ground rods;

4) Digging/drilling ground wells;

5) Encasing the ground grid in concrete;

6) Treating the soil with less resistive materials;

7) Bonding the ground grid to foundation rebar.

Except for the last option, these are all expensive solutions. Bonding to the rebar, however, potentially creates new issues such as corrosion of the rebar, damage to foundations during fault conditions, or the need for cathodic protection.

b. Current Division

While traditional methods seek to lower the grid resistance, an alternate solution, as discussed earlier, would be to decrease the amount of current flowing into the ground grid. Fig.2 shows that, by having alternate paths, the amount of current flowing into the ground grid can be reduced.

Most substations typically have incoming (or outgoing) lines with shield wires installed. It would be appropriate for the design engineer to investigate the properties of these shield wires and how they could affect current division as discussed in Annex C of IEEE Std. 80.

In some instances, the calculated split factor may not be substantial enough to limit the grid current to a safer level. Some possible solutions to all eviate this include the following.

1) Upsize the transmission/distribution shield/neutral wires.

2) Utilize aluminum shields instead of steel.

3) Install shields on unshielded lines

4) Consider connecting to a satellite ground grid.

Each of these methods must be carefully scrutinized and evaluated as they may result in hazardous voltage conditions at remote locations during a ground fault.

c. Surface Layer

From Figs. 1 and 2, the following can be concluded.

1) A minimum of 5 in of surface material should be used.

2) Increasing the surface material resistivity linearly increases the safely allowable step and touch voltages.

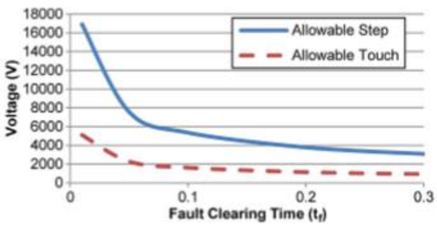


Fig.5

d. Fault Clearing Time

Limiting the duration of a ground fault on the system also reduces the hazardous touch and step voltages.

Fig. 3 shows the benefit derived from decreasing fault clearing times below 0.1s. The recommended practice, however, is to design a substation ground grid using the backup relaying clearing time of 1s.

This is a conservative estimate that will not falsely elevate safe step and touch voltages. Installing high speed primary and backup relaying schemes will allow the engineer to lower this backup protection tripping time, thus having a significant, and relatively low-cost, impact on designing a safe grounding grid.

5. DESIGN PROCEDURE OF GROUNDING GRID [1]

The grounding design of AIS and GIS is quite similar. But in GIS, separate grounding mat is made for the GIS building area and it is connected to the main grid. Here is the step for the grounding design which is applicable for both AIS and GIS substation.[7]

Step 1: The property map and general location plan of the substation should provide good estimates of the area to be grounded. A soil resistivity test will determine the soil resistivity profile and the soil model needed (that is, uniform or two-layer model).

Step 2: The conductor size is determined by equations given the fault current 3I0 should be the maximum expected future fault current that will be conducted by any conductor in the grounding system, and the time, tc, should reflect the maximum possible clearing time (including backup).

Step 3: The tolerable touch and step voltages are determined by equations. The choice of time, ts, is based on the judgment of the design engineer.

Step 4: The preliminary design should include a conductor loop surrounding the entire grounded area, plus adequate cross conductors to provide convenient access for equipment grounds, etc. The initial estimates of conductor spacing and ground rod locations should be based on the current IG and the area being grounded.

Step 5: Estimates of the preliminary resistance of the grounding system in the uniform soil can be deter-mined by the equations.For the final design, more accurate estimates of the resistance may be desired. Computer analysis based on modeling the components of the grounding system in detail can compute the resistance with a high degree of accuracy, assuming the soil model is chosen correctly.

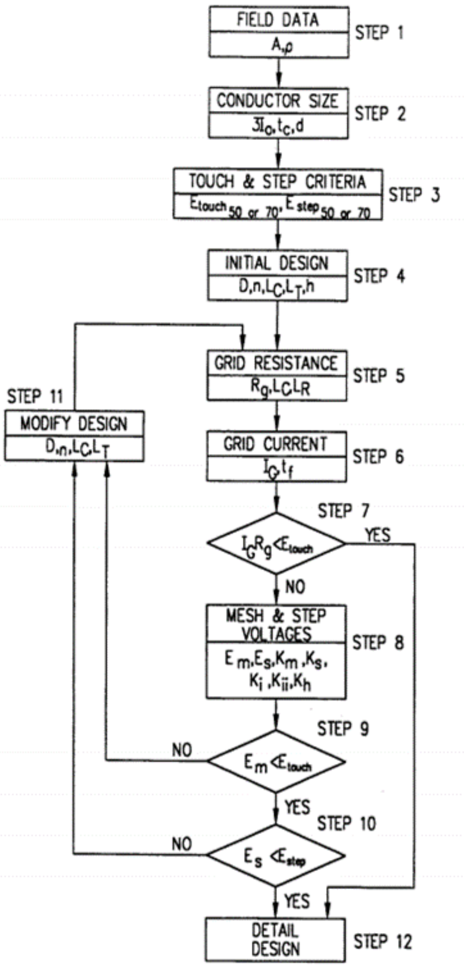
Step 6: The current IG is determined by the equations given in Clause 15. To prevent overdesign of the grounding system, only that portion of the total fault current, 3I0, that flows through the grid to remote earth should be used in designing the grid. The current IG should, however, reflect the worst fault type and location, the decrement factor, and any future system expansion.

Step 7: If the GPR of the preliminary design is below the tolerable touch voltage, no further analysis is necessary. Only additional conductor required to provide access to equipment grounds is necessary.

Step 8: The calculation of the mesh and step voltages for the grid as designed can be done by the approximate analysis techniques for uniform soil, or by the more accurate computer analysis techniques

Step 9: If the computed mesh voltage is below the tolerable touch voltage, the design may be complete (see Step 10). If the computed mesh voltage is greater than the tolerable touch voltage, the preliminary design should be revised (Step 11).

Step 10: If both the computed touch and step voltages are below the tolerable voltages, the design needs only the refinements required to provide access to equipment grounds. If not, the preliminary design must be revised (see Step 11).



Step 11: If either the step or touch tolerable limits are exceeded, revision of the grid design is required. These revisions may include smaller conductor spacings, additional ground rods, etc.

Step 12: After satisfying the step and touch voltage requirements, additional grid and ground rods may be required. The additional grid conductors may be required if the grid design does not include conductors near equipment to be grounded. Additional ground rods may be required at the base of surge arresters, transformer neutrals, etc. The final design should also be reviewed to eliminate hazards due to transferred potential and hazards associated with special areas of concern.

6. EXAMPLE OF HVPNL

Here the calculation is done for the Grounding design of one substation of Haryana Vidyut Prasaran Nigam Limited (HVPNL)

Input parameters

1) Symmetrical fault current in a substation for conductor Sizing I_f = 40000 A
2) Duration of a shock for determining allowable body current ts = 1sec
3) Surface gravel layer resistivity ρ_s = 3000 Ω - m
4) Surface gravel layer thickness h_s = 0.1 m

5) Soil resistivity ρ = 16 Ω - m
6) The depth of burial of earth material h = 0.6 m
7) Number of rods in switchyard Nr = 4
8) Length of a ground rod at each location Lr = 3 m
9) Maximum length in X - direction L = 360 m
10) Maximum length in Y - direction W = 330 m
11) The diameter of conductor/equivalent diameter in case of flat conductor d = 40 mm
12) Body weight = 50
13) Enter the value of k according to the weight of person k = 0.116
14) Enter resistance of the body of person R_B = 1000 Ω
15) Resistance of transmission line ground electrodes Rtg = 100
16) Resistance of distribution feeder found electrodes Rdg = 200
17) Impedance of transmission line Z= 0.546+0.103 Ω

Ampacity calculation:

Type of conductor: MILD STEEL
Reference temperature for material constants Tr = 20 °C
Thermal coefficient of resistivity at reference temperature α_r = 0.0045 °C
Fusing temperature of conductor Tm = 500 °C
Ambient temperature Ta = 50 °C
Ko = 202 °C
Resistivity of conductor at reference temperature ρ_r = 13.8 μΩ - m
Thermal capacity per unit volume TCAP = 3.8 $\frac{J}{cm3}$ * °C
9) Time duration for sizing the earth mat conductor tc = 1 sec
10) Current for sizing of earth mat conductor I = 40 kA
11) Soil resistivity for corrosion allowance ρ_{corr} = 3000 ohm-m

Grid configuration:

1) Grid shape : RECTANGULAR
2) Maximum length in X – direction L = 360 m
3) Maximum length in Y - direction W = 330 m
4) Spacing between parallel conductors D = 45m
5) Number of conductor along the length wise NL = 9
6) Number of conductor along the width wise Nw= 8
7) Number of electrodes Nr = 4
8) Length of individual electrode Lr = 3 m
9) Total length Lt = 5862 m
10) Total area of earth mat A = 118800 m^2
11) Total length of grid conductor Lc = 5850 m
12) Periphery length of the earthing equivalent area Lp = 1380 m
13) Total ground rods length Lr = 12 m

Output:

1) Ampacity calculation:

$$A_{mm^2} = l * \frac{1}{\sqrt{\left(\frac{TCAP\ *\ 10^{-4}}{t_c * \propto_r *\ \rho_r}\right)\ ln\left(\frac{K_0 +\ T_m}{K_0 +\ T_a}\right)}}$$

= 505.1927372 mm^2

2) Check the size of the selected conductor whether it is sufficient or not:

$$\sqrt{\left(A_{mm^2} * \frac{4}{\pi}\right)}$$

=25.36843761 mm

Minimum cross section required with corrosion allowance = 935.0200546 mm^2
Cross section of selected conductor = 1256 mm^2

3) The reduction factor (de – rating factor) Cs

$$C_s = 1 - \frac{0.09 * \left(1 - \frac{\rho}{\rho_s}\right)}{2 * h_{s+0.09}}$$

= 0.69131

4) Tolerable touch and step voltage:

$$E_{touch} = R_B + \frac{(R_B + 1.5 * \rho_s * C_s)\, k}{\sqrt{t_s}}$$

= 645.410515 V

$$E_{step} = R_B + \frac{(R_B + 6 * \rho_s * C_s)\, k}{\sqrt{t_s}}$$

= 2110.64206 V

5) Grid configuration:

$$R_g = \rho * \left[\frac{1}{L_T} + \frac{1}{\sqrt{20 * A}} * \left(1 + \frac{1}{1 + H * \sqrt{\frac{20}{A}}}\right)\right]$$

= 0.023409232 ohm

6. Calculation of attainable step and touch voltage:

- Geometric factor

  $n = n_a * n_b * n_c * n_d$

  = 8.48227235
- A corrective weighting factor that adjusts for the effects of inner conductors on the corner mesh

$$K_{ii} = \frac{1}{(2 * n)^{\frac{2}{n}}}$$

= 1

- The corrective weighting factor for grid depth

$$K_h = \sqrt{\left(1 + \left(\frac{H}{H_0}\right)\right)}$$

= 1.264911064

Spacing factor for mesh voltage

$$K_m = \frac{1}{2 * \pi} * \left[\ln\left[\frac{D^2}{16 * H * d} + \frac{(D + 2 * H)^2}{8 * D * d} - \frac{H}{4 * d}\right] + \frac{K_{ii}}{K_H} \ln\left[\frac{8}{\pi * (2 * n - 1)}\right]\right]$$

= 1.138001779

The correction factor for grid geometry

$$K_i = 0.644 + 0.148 * n$$

= 1.899376308

Effective length of mesh voltage

$$L_M = L_c + \left[1.55 + 1.22 * \left(\frac{L_r}{\sqrt{L_x^2 + L_y^2}}\right)\right] * L_R$$

= 5868.6899 m

Split factor :

$$S_f = \left[\frac{Z_{eq}}{Z_{eq} + R_g}\right]$$

= 0.960191145

Symmetrical grid current:

$I_g = S_f * I_f$

= 38407.6458

Decrement factor:

$D_f = 1$

Maximum grid current

$I_G = S_f * I_f$

= 38407.6458 A

Spacing factor for mesh voltage

$$K_s = \frac{1}{\pi} * \left[\frac{1}{2 * h} + \frac{1}{D + h} + \frac{1}{D} * (1 - 0.5^{n-2})\right]$$

= 0.279374784

Effective length of mesh voltage

$L_s = 0.75 * L_C + 0.85 * L_R$

= 4397.7 m

Mesh voltage

$$E_m = \frac{\rho * I_G * K_m * K_i}{L_M}$$

= 226.3343477 V

Step voltage

$$E_S = \frac{\rho * I_G * K_s * K_i}{L_s}$$

= 74.14985262 V

SAFETY CHECK:

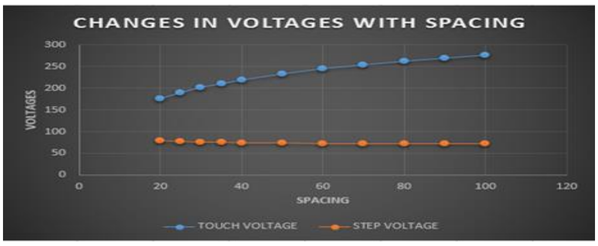
	Attainable voltage (V)	Tolerable voltage (V)
Touch voltage	226.3343477	645.410515
Step voltage	74.14985262	2110.64206

SO, OUR DESIGN IS CORRECT

7. EFFECT OF CHANGE IN AND TOUCH VOLTAGE WITH SPACING STEP

From the Graph, we can see that as the spacing between the conductor increases, the touch voltage is increases and the step voltage gets decreases. The change in step voltage with change in spacing is small compare to change in touch voltage.

SPACING	TOUCH VOLTAGE	STEP VOLTAGE
20	176.07	78.72
25	189.8	77.8
30	201.088	75.98
35	210.66	75.98
40	218.98	74.61
50	232.92	73.78
60	244.33	73.22
70	254.011	72.83
80	262.4	72.53
90	269.8	72.3
100	276.43	72.11



8. CONCLUSION

The design of grounding grid system for AIS and GIS substation is done by using IEEE 80-2000. For getting the lower step and touch voltages below their attainable value, the spacing between the conductor should be decreased. Also by using the Rods, the step and touch voltages can be decreased. The surface layer resistivity and surface layer thickness has a considerable effect on the step and touch volages.This paper has discussed several alternatives to the generally accepted practice of attempting to lower the ground grid resistance. It provides guidance for designing a safe and reliable substation ground grid for any substation.

9. REFERENCES

[1] IEEE guide for safety in AC substation grounding, IEEE standard 80-2000.
[2] CBIP manual on substation layout, Publication No. 299 ,2006.
[3] Andrew Ackerman, P.K.Sen, " Designing safe and reliable Grounding in AC substations with Poor Soil Resistivity: An Interpretation of IEEE Std. 80'',IEEE Tranjection on Industry Application,Vol_49,No.4July/August 2013.
[4] Chien- Hsing Lee, "Comparison of 161/69-kV Grounding Grid Design Between Indoor-Type and Outdoor-Type Substations" ,IEEE Tranjection on Power Delivery,Vol.20,No.2,April 2005.
[5] Raj Nagarsheth, Sushant Singh, "Study of Gas insulated substation and its comparison with ais insulated substation" , Electrical Power and Energy Systems 55(2014) 481-485
[6] M.G.Unde,B.E.Kushare, " Cost Effective Design of Grounding Grid using Ground Rods-a Case Study",2012.
[7] Tosak Thasananutariya, Knathip Spuntupong, Somchai Chatratana, "Design Of Grounding System For GIS Indoor Substation'',2004.
[8] Kaustubh A. Vyas, and J.G. Jamnani, "Optimal Design and Development of Softwarefor Design of Substation Grounding System'' , Institute Of Technology, Nirma University, Ahmedabad – 382 481, 08-10 December, 2011.
[9] M. Usman Aslam, Muhammad Usman Cheema, Muhammad Bilal Cheema, Muhammad Samran, "Design Analysis and Optimization of Ground Grid Mesh of Extra High Voltage Substation using an Intelligent Software'' 2014.
[10] Hao Zhang,Qiang Liu,Meirong Chen,Wei Wang,''Optimization Design of Grounding Grid Model for 500kV Substation" ,2012.
[11] LARUELLE Elodie, KIEFFEL Yannick, "Environmental impact comparison between a 220 kV Gas-Insulated Substation and a 220 kV Air-Insulation Substation", 2013.

NOMENCLATURE

TCAP	Thermal Capacity per unit volume
ρ	Soil resistivity, Ω·m
ρ_s	Surface layer resistivity, Ω·m
$3I_0$	Symmetrical fault current in amps
A	total area enclosed by grounding grid,m^2
C_s	Surface layer derating factor
d	Diameter of grid conductor, m
D	Spacing between parallel conductors, m
D_f	Decrement factor for determining IG
D_m	Max distance between any two points on grid, m
E_m	Mesh voltage at the center of the corner mesh, V
E_s	Step voltage, V
E_{step50}	Tolerable step voltage for 50kg human body, V
E_{step70}	Tolerable step voltage for 70kg human body, V
$E_{touch50}$	Tolerable touch voltage for 50kg human body, V

$E_{touch70}$ Tolerable touch voltage for 70kg human body, V

h Depth of ground grid conductors,

h_s Surface layer thickness, m

I_G Maximum grid current that flows between ground grid and surrounding surface.

I_g Symmetrical grid current, A

K Reflection factor between different resistivities

K_h Corrective weighting factor that emphasizes the Effect of grid depth.

K_i Correction factor for grid geometry, simplified method

K_{ii} Corrective weighting factor that adjusts for the effects of inner conductors on the corner mesh, simplified method

K_m Spacing factor for mesh voltage, simplified method

K_s Spacing factor for step voltage, simplified method

L_c Total length of grid conductor, m

L_m Effective length of Lc+ LR for mesh voltage, m

L_R Total length of ground rods, m

L_r Length of ground rod at each location,m

L_S Effective length of Lc + LR for step voltage, m

L_T Total effective length of grounding system conductor, including grid and ground rods, m

L_X Maximum length of grid conductor in x direction, m

L_Y Maximum length of grid conductors in y direction, m

n Geometric factor composed of factors na, nb, nc, and nd

n_R Number of rods placed in area A

R_g Resistance of grounding system, Ω

S_f Fault current division factor (split factor)

t_c Duration of fault current for sizing ground conductor, s

t_f Duration of fault current for determining decrement factor, s

t_s Duration of shock for determining allowable body current, s