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Earth Mat Design for a 66kv Substation

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ABSTRACT: This paper presents the design of Earthing system for 66 KV substation and calculation of its parameters. Successful operation of entire power system depends to a considerable extent on efficient and satisfactory performance of substations. Hence substations in general can be considered as heart of overall power system. In any substation, a well-designed grounding plays an important role. Since absence of safe and effective grounding system can result in mal-operation or non-operation of control and protective devices, grounding system design deserves considerable attention for all the substations. Grounding system has to be safe as it is directly concerned with safety of persons working within the substation. Main purpose of this work is designing safe and cost effective grounding systems for 66KV substations. Initially significance of Earthing is explained & methodology for design of substation grounding system is discussed for 66KV substation. This paper mentions the calculation of the desired parameters for 66 kV substation.

KEYWORDS: Earthing, Earth electrodes, Ground grid, 66 KV substations, Power systems, Safety, Touch and Step voltages

I. INTRODUCTION

Earth behaves as an Electrical conductor but its characteristics is that its conductivity is variable and unpredictable. The resistance of an earth connection varies with earth's composition, chemical contents, moisture, temperature, season of the year, depth and diameter of rod and other reasons[1]. The resistance offered to AC and DC also differs considerably. Earthing practices adopted at Generating Stations, Substations, Distribution structures and lines are of great importance. It is however observed that this item is most often neglected. Substation earthing system is essential not only to provide the protection of people working in the vicinity of earthed facilities and equipment's against danger of electric shock but to maintain proper function of electrical system. The object of earthing system is to provide a surface under and around a station, which shall be at a uniform potential (nearly zero or absolute earth potential). This Earth surface should be as nearly as possible to the system. This is in order to ensure that, all parts of apparatus other than live parts and attending personnel shall be at earth potential at all times. Due to this there exists no potential difference, which could cause shock or injury to a person, when short circuit or any other type of abnormalities takes place. This paper is concerned with earthing practices and design for outdoor AC substation of 66KV for power frequency in the range of 50 Hz.

II. ADVANTAGES OF EARTHING

- Reduced operation & Maintenance cost
- Reduction in magnitude of transient over voltages.
- Improve lightning protection.
- Simplification of ground fault location.
- Improved system and equipment fault protection.
- Improved service reliability
- Greater safety for personnel & equipment
- Prompt and consistent operation of protective devices during earth fault.

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III. IMPORTANCE

The earthing system in a plant / facility is very important for a few reasons, all of which are related to either the protection of people and equipment and/or the optimal operation of the electrical system. These include: Equipotential bonding of conductive objects to the earthing system prevent the presence of dangerous voltages between objects (and earth). The earthing system provides a low resistance return path for earth faults within the plant, which protects both personnel and equipment. The earthing system provides a low resistance path for voltage transients such as lightning surges and over voltages. Equipotential bonding helps prevent electrostatic build up and discharge, which can cause sparks with enough energy to ignite flammable atmospheres. The earthing system provides a reference potential for electronic circuits and helps reduce electrical noise for electronic, instrumentation and communication systems.

IV. EARTHING DESIGN FOR 66KV SUBSTATION

1. EARTHING

"Earthing means an electrical connection to the general mass of earth to provide safe passage to fault current to enable to operate protective devices and provide safety to personnel and Equipment's."[2]

2. TYPES OF EARTHING

EQUIPMENT EARTHING

It comprises earthing of all metal work of electrical equipment other than parts which are normally live or current carrying. This is done to ensure effective operation of the protective gear in the event of leakage through such metal work, the potential of which with respect to neighbouring objects may attain a value which would cause danger to life or risk of fire.

SYSTEM EARTHING

Earthing done to limit the potential of live conductors with respect to earth to values which the insulation of the system is designed to withstand and this to ensure the security of the system.

3. EARTH ELECTRODE

A Galvanized Iron (GI) pipe in intimate contact with and providing an electrical connection to earth.

4. EARTHING GRID

A system of a number of interconnected, horizontal bare conductors buried in the earth, providing a common ground for electrical devices and metallic structures, usually in one specific location.

5. TOUCH VOLTAGE (E TOUCH)

The potential difference between a ground metallic structure and a point on the earth's surface separated by a distance equal to the normal maximum horizontal reach of a person, approximately one meter.

6. STEP VOLTAGE (E STEP)

The potential difference between two points on the earth's surface separated by distance of one pace that will be assumed to be one meter in the direction of maximum potential gradient.

7. MESH VOLTAGE (E MESH)

The maximum touch voltage to be found within a mesh of an earthing grid.

8.EARTHING LEAD

It is the conductor by which the final connection to the earth is made. Its size should be of sufficient cross sectional area so that it will not fuse under worst fault condition.

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9. EARTHING GRID

An earthing grid is formed by means of bare GI rod of appropriate size buried at a depth of about 600 mm below the ground level and connected to earth electrodes. The connection between electrodes and the grid shall be means of two separate and distinct connections made with 75 mm x 8 mm GI flat.

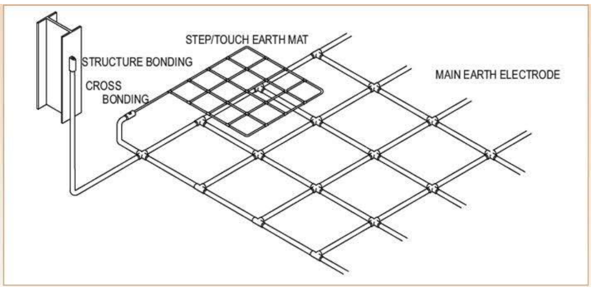

Fig.1:*Earth mat*

The connection between the GI flat and the GI rod shall be made by welding, while that between the earth electrode and the GI flats through GI links by bolted joints. The earth electrodes shall be provided at the outer periphery of the grid. As far as possible the earthing grid conductors shall not pass through the foundation block of the equipment. All crossings between longitudinal conductors and transverse conductors shall be joined by welding. The longitudinal and transverse conductors of the earthing grid shall be suitably spaced so as to keep the step and touch voltage within the acceptable limit. However the overall length of the earthing grid conductors shall not be less than the calculated length. The size of the earthing grid conductor shall be decided based on the incoming system voltage and fault level . The fault level considered shall take into account the anticipated increase in fault current during the life span of the station.

10. EARTH MAT DESIGN

Earthing System in a Sub Station comprises of Earth Mat or Grid, Earth Electrode, Earthing Conductor and Earth Connectors. Primary requirement of Earthing is to have a low earth resistance. Substation involves many Earthlings through individual Electrodes, which will have fairly high resistance. But if these individual electrodes are inter linked inside the soil, it increases the area in contact with soil and creates number of parallel paths[3]. Hence the value of the earth resistance in the inter linked state which is called combined earth value which will be much lower than the individual value. The inter link is made through flat or rod conductor which is called as Earth Mat or Grid. It keeps the surface of substation equipment as nearly as absolute earth potential as possible. To achieve the primary requirement of Earthing system, the Earth Mat should be design properly by considering the safe limit of Step Potential, Touch Potential and Transfer Potential.

11. THE FACTORS WHICH INFLUENCE THE EARTH MAT DESIGN ARE:

Magnitude of Fault Current, Duration of Fault, Soil Resistivity, Resistivity of Surface Material, Shock Duration Material of Earth Mat, Conductor Earthing Mat Geometry.

12. THE DESIGN PARAMETERS ARE:

Size of Earth Grid Conductor, Safe Step and Touch Potential, Mesh Potential (Emesh), Grid configuration for Safe Operation, Number of Electrodes required

13. DESIGN PROCEDURE

The Investigation of soil characteristics has to be done along with the determination of maximum ground current. After that preliminary designing of grounding system need to done. After that calculation are made possible including

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calculation of resistance of grounding system, calculation of maximum grid potential rise, calculation of step voltages at periphery, calculation of internal step and touch voltages. After the investigation of transferred potential and special danger points are made correction of preliminary design can be made if any necessary. Construction of earthing system. Field measurement of resistance of earthing system. Review and modification of earthing system, if necessary.

IV. MATHEMATICAL CALCULATION

1. **Prerequisites**

The following information is required / desirable before starting the calculation:

• A layout of the site.
• Maximum earth fault current into the earthing grid.
• Maximum fault clearing time.
• Ambient (or soil) temperature at the site.
• Soil resistivity measurements at the site (for touch and step only).
• Resistivity of any surface layers intended to be laid (for touch and step only).

2. Step and touch voltage criteria

The tolerable step voltage criteria is

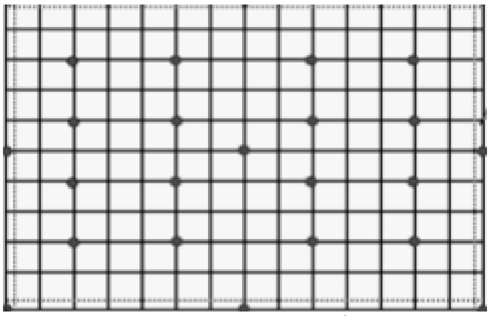

Fig.2: schematic diagram of earth mat

$Estep$= [1000+(6×Cs×ρs)]*(0.116/$\sqrt{ts}$)
The tolerable touch voltage criteria is
$Etouch$= [1000+(1.5×Cs×ρs)]*(0.116/$\sqrt{ts}$)
Where,
E$step$ = the step voltage in V
E$touch$ = the touch voltage in V
Cs = 1for no protective layer
Ps = the resistivity of the surface material in Ω·m
Ts = the duration of shock current in seconds
The earth grid conductor size formula
I=$A\sqrt{((TCAP\times104)/(tc\times\alpha r\times\rho r))}$ *$ln(k0+TM/k0+Ta)$
Where,
I = rms value in kA
A = conductor sectional size in mm²
Tm = maximum allowable temperature in ˚C
Ta = ambient temperature for material constants in˚C
$\alpha_\circ$= thermal coefficient of resistivity at 0˚C

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α_r = thermal coefficient of resistivity at reference temperature Tr
ρ_r = the resistivity of the ground conductor at reference temperature Tr in uA/cm3
$K_\circ = 1/\alpha_\circ$ or $1/\alpha_\circ$ - Tr
tc = time of current flow in sec
TCAP = thermal capacity factor

3.Evaluation of ground resistance

A good grounding system provides a low resistance to remote earth in order to minimize the GPR. For most transmission and other large substations, the ground resistance is usually about 1 Ω or less. In smaller distribution substations, the usually acceptable range is from 1 Ω to 5 Ω, depending on the local conditions.[3]

For calculation of grounding resistance, the following formula is used
$Rg= \rho[1/LT+1/\sqrt{20A}(1+(1/1+h\sqrt{20A}))]$
Where
ρ = soil resistivity Ωm
Lt = total length of grid conductor m
A = total area enclosed by earth grid m2
h = depth of earth grid conductor m

For calculation of grid current,
$IG= (CP\times Df\times Sf\times I)$
For calculation of grid potential rise
$GPR=(IG\times Rg)$

4. Actual Step Potential & Touch Potential Calculations

Mesh voltage :
$Em =[\rho\times Km\times Ki\times Kim/LL+LB+LA+(1.15\times LE)]$
Step voltage :
$Es =[\rho\times Km\times Ki\times Kis/LL+LB+LA+(1.15\times LE)]$
Where
ρ = soil resistivity, ohms-m
Em = mesh voltage at the center of corner mesh in V
Es = step voltage between point in V
Km = spacing factor for mesh voltage
Kis = spacing factor of step voltage
Kim = correct factor for grid geometry
LL= Length of grid conductor along length of switch yard
LB= Length of grid conductor along breadth of switch yard
LA= Length of riser and auxiliary mat in switch yard
LE= Length of earth electrodes in switch yard
LT= Total length of earth conductor in switch yard
$LT=(LL+LB+LA+LE)$

V. RESULT

Grid resistance = 0.24Ω
Ground potential rise = 3570V

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Tolerable touch potential = 717V
Attainable touch voltage = 670.70V
Tolerable step voltage = 2379V
Attainable step voltage = 5698V

VI. CONCLUSION

This paper has a focus on designing of a 66 kV AC substation earthing system. The results for earthing system are obtained by computational method. For earthing conductor and vertical earth electrode, mild steel are used. The step by step approach for designing a substation earthing system is presented. The various kinds of conductor sizes for earth equipment are mentioned in this paper. Construction of earthing grid is expressed in here. The step and touch voltages are calculated.Substation grounding is a crucial part of substation design. The design has to be both safe and reliable. There are many steps to design a safe and effective grid. This project provides equations that are involved with a grid design. Finally an equation is provided using real world data. This example was designed to meet the design criteria for a safe ground grid.

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