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Design of Grounding System for Substation

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ABSTRACT

This paper presents 230/66 kV, substation grounding system and calculation results of required parameters. The grounding system is essential to protect people working or walking in the vicinity of earthed facilities and equipments against the danger of electric shock. This paper provides the floor surface either assures an effective insulation from earth potential or effectively equipment to a close mesh grid. Calculations of grounding grid system in the substation area which the top soil-layer resistivity is less than the bottom-layer resistivity, can lessen the number of ground rod used in the grid because the value of Ground Potential Rise (GPR) is insignificantly different. Essential equations are used in the design of grounding system to get desired parameters such as touch and step voltage criteria for safety, earth resistance, grid resistance, maximum grid current, minimum conductor size and electrode size, maximum fault current level and resistivity of soil. Calculations of three separate earthing (body earth, neutral earth and main earthing) are described.

KEYWORDS: *soil resistivity, conductor size, square shaped grid, step voltage, touch voltage, grid resistance*

1. INTRODUCTION

Earthing of installations and equipment is an issue that crosses the boundaries of the various disciplines involved in the construction and equipping of a modern commercial or industrial building. In this document an overall earthing approach is presented to serve as a basic guideline for earthing and interference suppression that can be used by multi-disciplinary teams. In general any earthing system needs to satisfy three demands.

Although requirements for these three aspects are often specified separately, the implementation of them requires an integrated systems approach. All interconnected ground facilities in a specific area is called grounding system. The thin layer of material such as rock, clay, chalk which covers our planet whatever so earth is referred as a zero potential in the world of electricity. These electric potential at any point is conventionally taken as zero. Substation Grounding system is generally divided into three conditions;

A. Low voltage grounding system
B. Solidly grounding system
C. Reactance grounding system
D. Resistance grounding system
E. Solidly grounding system of the substation may be specially established. It is divided into three conditions, Small station (such as 6.6/0.4kV, 11/0.4kV) Majorstation(suchas22/0.4kV,33/11kV,33/0.4kV,66/33/11kV)
   Largestation (suchas132/66kV,500/230/132kV)

2. MATHEMATICAL REVIEW

For design and calculating of 230/66 kV system that will need fully protection equipments and very safe condition. At least two legs attach diagonally opposite on each metal structure shall be provided with an earthing conductor. Substation equipments are very valuable than any other facilities in a power system. The switchyard protection equipments, some of which are not only compound grounded but also separate earthed depend on their functions. By using following equations. minimum cross-sectional area in circular mils is

$$A_{kcmil} = I \times K_f \sqrt{t_c} \quad (1)$$

$$A_{mm^2} = \pi d^2/4 \quad (2)$$

$$E_{step70} = \frac{(1000 + 6C_S \cdot \rho_S)0.157}{\sqrt{t_S}} \quad (3)$$

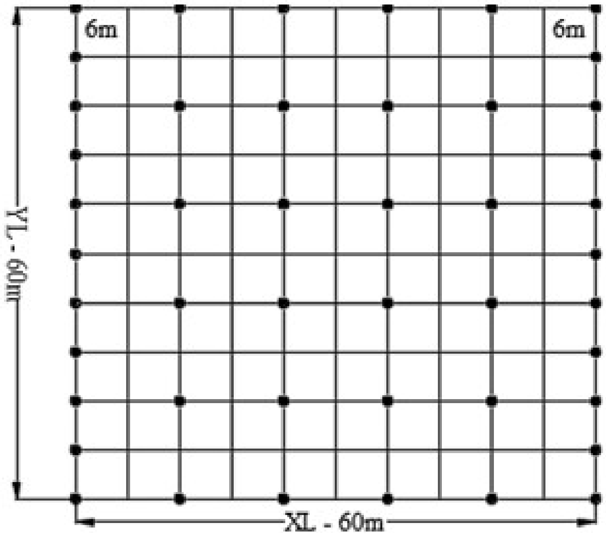
$$E_{touch70} = \frac{(1000 + 1.5C_S \cdot \rho_S)0.157}{\sqrt{t_S}} \quad (4)$$

$$E_m = \frac{\rho \cdot K_m \cdot K_i \cdot I_G}{L_M} \text{ ,Mesh Voltage} \quad (5)$$

3. SQUARE SHAPED GRID

Substation Available Area, A = 60m × 60m = 3600m²
Grid Spacing, = 6m
Grid burial depth, h = 0.8-1 m (f 230kV and above level)
Length of each Ground rod, L_r = 4m
Max Line to Ground Fault Current, I_f = 7.0kV, 66kV Bus side
Duration of fault in sec, t_c = 1 sec
Primary Line Voltage = 230,000V
Secondary Line Voltage = 66,000V
Soil resistivity, ρ = 48 Ω-m (Wenner Four Pin Method)
Surface crushed rock resistivity, ρ_s = 2500 Ω-m
Number of Earth rod = 46 Nos
For Square shaped grid mat

Figure1.Preliminary Calculation of Touch and Step Voltage



1. Table Soil Resistivity Measurement Record Table

	Test Pin Spacing	Meter Display Ohm -meter	Remark
Direction 1	4	65	
Direction 2	4	33	
Direction 3	4	60	
Direction 4	4	36	Avg 48 -Ωm
Direction 5	4	56	
Direction 6	4	40	

2. Result Table for Substation Grounding System

Reflection factor (K)	-0.96
Reduction factor (C_s)	0.7
Step voltage (E_{step70})	2553V
Touch voltage ($E_{touch70}$)	804.7V
Total length of all earth rod (L_R)	184m
Total length of horizontal conductor (L_C)	1320m
Parameter length of grid conductor (L_g)	240m
Total ground conductor length (L_T)	1504m
Grid resistance (R_g)	0.38Ω
Grid current (I_G)	4200A
Ground Potential Rise (GPR)	1596V
Geometrical factor (K_m)	0.633
Irregularity factor (K_i)	2.272
Mesh voltage (E_m)	179.44V
Effective buried conductor length (L_s)	1153.2
Step voltage (E_{step})	119.46V

3Comparison of Permissible and Designed Values

	Designed	Permissible/ Allowed
Step Voltage (E_s)	119.46V	<2553V
Mesh Voltage(E_m)	179.44V	<804.7V
Grid Resistance ; R_g	0.38 Ω	1 Ω
Earth Mat Design is safe and Completed		

4. CONCLUSIONS

The grounding system at a system substation consists of a minimum of four earth electrodes installed around the inside perimeter of the substation and connected together with the earth mesh the exact spacing of the electrodes will be determined by the final design which will be based on local conditions, resistivity of the area and space available for electrodes. The spacing between should be greater than the electrodes' length. Although the earth mesh will often result in a low enough resistance without the use of electrodes, fifty electrodes are still necessary in this to ensure the fault level capability and forty-six electrodes are used for neutral ground grid. Electrodes are also required in case of the drying out of the soil at the depth of the earth mesh in long dry spells.

The size of the high voltage grounding conductors is determined by the earth fault level but in any case shall be not smaller than 70 mm^2 copper. The main low voltage grounding conductor is between the low voltage ground electrodes and the supply main switchboard ground bar. The size of the main grounding conductor shall not be smaller than 25 mm^2 copper.

In this paper, design calculation and design procedure of grounding system can be expressed. A good grounding system for provides a low resistance to remote earth in order to minimize the ground potential rise. For most transmission and other large substation, the ground resistance is usually about 1Ω of less. In smaller distribution substation the usually acceptable range is from 1 to 5Ω, depending on local conditions.

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