

Circumstances affecting the protection against electrode potential rise (EPR)

J. Ladányi, Gy. Varjú

Department of Electric Power Engineering, Power Systems and Environment Group
Budapest University of Technology and Economics
Egry József u. 18, 2nd floor, H-1111 Budapest (Hungary)
Phone number: +0036 1 4633021, fax: +0036 1 4633013, e-mail: ladanyi.jozsef@vet.bme.hu

1. Brief introduction

Required power of the big cities keeps growing year by year. It is necessary to establish new high voltage (HV) / medium voltage (MV) transformer stations to satisfy power demand in densely populated urban areas. The area available for installing HV/MV substation is restricted and becomes more and more expensive in the city. Considering this condition earthing resistance of the substations must be low enough to satisfy safety (step voltage, touch voltage, earth potential rise) and electromagnetic compatibility requirements (earth potential rise, potential difference inside the station affecting the secondary wiring).

In this paper the earthing resistance of substations with different earth electrode and soil structures is investigated by simulation studies with the use of CDEGS (Current Distribution, Electromagnetic Fields, Grounding and Soil Structure Analysis) software code. The paper presents the effect of grid geometry, soil characteristics, the effectiveness of the vertical earth rods and the conductor diameter.

Simulation study has been done to assess the effect of the following circumstances affecting the earthing resistance:

- Geometrical dimensions of substation earthing system
- Mesh size of the grid
- Application of the driven vertical rod electrodes (deep earth rods)
- Soil characteristics (value of the specific resistivity and stratified structure)

In case of simply grid arrangements the earthing resistance can be determined with analytical expressions given in the technical literatures [1] [2]. Nowadays the earthing resistance of complex earthing systems with the consideration of the actual soil resistivity values and structures of stratified earth can also be calculated by sophisticated computer codes based on numerical techniques [3].

In this paper the effects of the above listed conditions on the earthing resistance are investigated and the relative importance of the different parameters are evaluated.

2. Simulation technique

The resistance of an investigated earthing system has been calculated, by definition, as the ratio of the earth potential rise (EPR) and the current causing it (Ohm's law). That is why current injection technique has been used. Thus, a test current has been injected into the grid, which has caused a potential rise on the grid. The ratio of the potential rise to the remote earth at the current injection point and to the current value gives the earthing resistance.

3. Examined variations

Earthing resistance depends on above-mentioned circumstances.

In this paper the following effects were studied:

- Total length of conductors (mesh size of theirs)

- Diameter of the conductors
- Soil structure, uniform and two layered
- Value of the soil resistivity
- Application of driven vertical rod electrodes
- Theirs combinations

In addition the electrode potential rise (EPR) was also investigated.

A. Soil characteristic

From the point of view of earthing resistance the soil resistivity, stratification, thickness of layers, number of layers are determinant.

Two cases were examined, on the one hand the soil is uniform and the other hand it was a two-layer soil.

4. Presentation of the results

The earthing resistance obtained from the simulations are usually plotted vs. the total length of conductors.

Earthing resistance is directly proportional to soil resistivity in that case of uniform soil while this relation is non-linear when the soil is non-uniform (e.g. stratified).

B. Vertical earth rods

Accordingly to the standards concentrated earthing have to apply for the surge arresters and the star point of the transformer(s) in the transformer stations. It can be vertical earth rod. The effect of such rods has also been investigated.

C. Earth potential rise (EPR)

Different soil structures causes different earth potential rise. In addition decrement of the potential cone depends on soil structure. Two cases were investigated: on the one hand the soil is two layered and the bottom layer has constant resistivity, and the other hand the top layer has constant resistivity.

5. Investigation of not conventional arrangement

The earthing system of a not conventional underground 120/10 kV substation is investigated in the followings.

6. Conclusion

In this paper sophisticated computer codes based on numerical techniques [3] are applied for the investigation of the earthing resistance of complex earthing systems with the consideration of the different soil resistivity values and stratified earth.

From the numerical results obtained, the following main conclusions can be drawn:

- The decrease of the mesh size of the grid results in significant decrease in the earthing resistance up to size 5 by 5 m.
- In case of stratified soil structure the earthing resistance does not change anymore proportionally to the resistivity of the soil.
- The application of vertical rods improves the earthing resistance significantly only in that case when the resistivity of the lower layer is the smaller one.
- In case of two-layered soil with low resistivity upper layer (wet organic soil), and very high resistivity bottom layer (bedrock) the earthing resistance is essentially determined by the upper layer.
- The diameter of the conductor constituting the grid has of minor effect on the magnitude of the earthing resistance.
- EPR and wideness of the potential cone depends on soil structure.
- In that case when the resistivity of the bottom layer is constant and the resistivity of the top layer is increasing, the maximum value of EPR changes approximately proportionally to the resistivity of the upper layer.
- In the opposite case wideness of the potential cone grows wider with increasing of the bottom layer resistivity.

References

- [1] G.F. Tagg, *Earth resistances*, George Newnes Limited, London (1964)
- [2] IEEE Standard 80-2000, *IEEE Guide for Safety in AC Substation Grounding* (2000)
- [3] Current Distribution, Electromagnetic Fields, Grounding and Soil Structure Analysis (CDEGS) *Software package manuals*, Safe Engineering Services & technologies Ltd., Montreal, Quebec, Canada. Application Version 13.
- [4] J. Ladányi, *Examination of the effect of the earthing grid material in high voltage substations*, M.Sc. thesis, Budapest (2006), (in Hungarian)