A COMPUTATIONAL PROCEDURE TO ESTIMATE THE FUNDAMENTAL PARAMETERS IN GROUNDING GRID DESIGN

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Abstract

The grounding grid design must be made in such a way that the fundamental parameters do not exceed the safety limits. The estimation of the values of the grid resistance, the touch voltage and the step voltage is carried out by means of formulas and algorithms based on the average potential methods. In this framework, the average potential is often obtained taking into account the mutual influence between the grid electrodes and considering that the current distribution along each electrode is uniform. However, the physical phenomena shows that the current derived to earth is distributed in the grounding grid in such a way that the potential is constant in it. A good approximation to the current distribution that makes constant the potential on the grounding grid, can be performed by a linear programming algorithm. In this communication, we present some results obtained by applying this methodology in the estimation of the grid resistance and the surface potential of several grounding grids. With the aim of improve the features of a grounding grid we tackle the problem of modifying its mesh geometry, keeping fixed the total length of the electrodes and the meshes number, and this also shows the versatility of our methodology. Finally we compare grounding grids with different meshes number and we check that optimizing its geometries, we can get touch and step voltages comparables with the ones obtained by considering equally space grounding grids with a greater meshes number, what can provide a substantial save of material.

1 Introduction

The main objective of the grounding systems is to dissipate a current injection at an electrical substation produced by an accidental over-potential. The soil under the substation becomes the diffuser medium, which is a heterogeneous semiconductor material, but it is considered homogeneous in almost all the models and standards, as well as we do at the development of this communication. The grounding system is performed by linear electrodes building a grid and it can be considered as a perfect conductor.Therefore, the grounding grid distributes the injected current instantly all over his periphery, which is the starting point for the transmission to the earth of the electrostatic field produced in response to this physical phenomena. Consequently, the potential associated to this field appears in the substation outskirts and particularly on the ground surface, and it basically depends on the grounding grid shape. In relation to this grounding grid performance, it must be achieved an agreement between the potential values over the ground surface and the potential gradient between points of it, to safeguard that the touch and step potentials do not exceed the limits of a safely tolerable voltage [1].

Since not-current flow through the ground surface exists, the potential is characterized for being constant on the grid surface. Even more, if we assume that the ground surface is flat, then the method of images can be used and hence the potential will be unequally established for being constant on the grounding grid and its symmetrical one.

2 Potential approximation methods

2.1 The average potential methods

The application of the average potential methods is based on, ([2]):

- Considering the grid electrodes as unidimensional elements.
- Supposing the current distribution constant along the electrodes or the electrodes segments into which the grounding grid is broken up.
- Limiting the grid geometry shape in order to work with parallel or perpendicular segments.

It must be point out that the influence coefficient for one segment over another only depends on the geometry of both segments and it can be calculated analytically in all case except for aligned segments, in which case it is calculate in an approximated way. In any case, the potential at *i-th* segment due to *j-th* segment can be expressed as the influence coefficient times the current density of the *j-th* segment. Moreover, this current density makes constant the potential value over the grounding grid surface.

The difficulties to get fitted conditions to obtain strictly positive solutions for the corresponding algebraic system, lead often to adopt the assumption of uniform current distribution all over the grid and to assign as current density in each electrode segment the result of the ratio between the current density and the segment length. Then, the average potential on the grid surface and so its resistance, can be already obtained [3].

2.2 The extremal masses method

The knowledge of the equal potential on the grid surface leads to obtain the current density into the grounding grid. The properties of the electrical potential allow to rewrite the problem of its obtaining as an optimization problem. Specifically, the problem becomes into obtaining the minimum, among the current distributions in the grid, of the maximum value of the electrical potential on the grid surface. This last problem can be approximated discretizing the grounding grid [4, 5].

The grid discretizing consists on assimilating the grid surface to a set of evaluation points and on concentrating the current distribution in another set of mass points placed at the electrodes axis. This differentiation between mass points and evaluation points avoids the troubles associated with the auto-influence coefficients, and at the same time keeps the convergence of the approximated solution to the initial one. Moreover, the discrete optimization problem becomes easily into a linear programming problem [5, 6].

To show the applicability of the extremal masses method, we present the analysis of several academic grounding system configurations, for which have been computed the electrical potential and the fundamental parameters in the grounding grid design [7]. The general characteristics of all chosen examples are the following ones:

- Homogeneous soil with resistivity of $100\Omega m$.

- Squared grids of $30m$ of side, buried at $50cm$.

- Electrodes of $2cm$ diameter.
- Rods $3m$ long with diameter of $6.4cm$.
- Fault current intensity of 10KA.

The first example displays an equally spaced 16 mesh grid with rods in all its periphery nodes. The total length of the electrodes is $348m$. Figure 1 displays the surface potential and its level curves. The step voltage, computed as the maximum difference between points of the surface earth separated by a distance of one meter, is 1.978KV. The touch voltage, computed as the maximum difference between the grounding grid potential and the potential in an earth surface of $31.4 \times 31.4m^2$ that covers the grounding grid, is 3.583KV.

In the second example we have considered an equally spaced 256 mesh grid with rods in all its periphery nodes. The total length of the electrodes is 1,212m. Figure 2 displays the surface potential and its level curves. The step voltage is 1.463KV and the touch voltage is 1.979KV. In the two preceding figures we can see how the drastic increasing of the number of electrodes has smooth out the surface potential.

In order to show the method versatility and to obtain some conclusions in relation to the different geometries of a grounding grid, we have analyzed the variation of the fundamental parameters when the relative position of the electrodes is modified. The results show an improvement of these values when considering non uniform geometries, which are more in keeping with the current distribution in squared grounding grids. For instance, we have obtained for a 64 mesh grid without rods a reduction of 4% in the touch voltage when optimizing the geometry of its meshes. Figure 3 displays the surface potential and the geometry of the optimized 64 mesh grid, of which smallest electrodes are $1.5m$ long. Moreover, in the development of this analysis we have obtained other interesting results. For instance, in comparing a 64 mesh grid without rods and whose geometry has been optimized with an equally spaced 256 mesh grid without rods, we obtain a reduction of 9% in the touch voltages with an increase of 89% in material. This fact shows that the geometry optimization allows significant reductions in the touch voltages without a drastic increase in material.

3 Conclusions

As it is well known, the deepness of the grid burying and the grid perimeter are the most relevant characteristics of the grounding grids to determine the fundamental parameters. With these characteristics previously fixed, this communication shows that a fitted computation of the potentials and the consideration of unequally spaced grids can conduct to the designer to choose grounding grids for which there is a great save of material.

From the study developed in this communication it is clear the interest in creating a meeting point for the two methods of calculus before mentioned. For this, and once the unidimensional approximation of the problem has been assumed, it suffices to keep the division criterium between mass points and evaluation points, employed in the extremal masses method, and to replace, in the average potential method, the punctual masses by charge segments of uniformly distributed mass and the evaluation points by evaluation segments. In this way, to construct the influence matrix, neither the approximation of the influence coefficients in the case of aligned electrodes nor the consideration of the same number of mass segments as evaluation segments are necessary. The combination of both methods would allow the designer to solve the corresponding algebraic system by means of linear programming methods. Besides, this new modelization allows the consideration, for instance, of less evaluation than mass segments, what accelerate the computational time of the solution since this time in the linear programming problem depends on the smallest dimension of the constraint matrix.

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