FEASIBILITY OF ELECTRICAL SEPARATION OF PROXIMATE GROUNDING SYSTEMS AS A FUNCTION OF SOIL STRUCTURE

Sharon Tee and Farid P. Dawalibi
Safe Engineering Services & technologies ltd.
1544 Viel, Montreal, Quebec, Canada, H3M 1G4
Email: info@sestech.com; Web Site: www.sestech.com

Abstract: *Electrical separation of proximate grounding systems has been the subject of much heated debate in the past and continues to generate much interest and discussion, particularly when the target grounding systems belong to different utilities. Essentially, the main argument used by the advocates of electrical separation is to prevent transfer of high ground potential rise from the neighboring but physically separate grounding system to their own system, which is typically a lower voltage installation. The main objective of this paper is to determine the feasibility and adequacy of electrical separation of grounding systems buried in a variety of soil structures, by carrying out a computerized parametric analysis. The computation results show that the nature of the soil structure has a significant influence on the intensity of the conductive coupling between grounds. Transferred potentials from one system to the other may range from a fraction of one percent to more than 90%, in most practical cases examined. Most of the results shown in this paper have never been published before.*

Keywords: Ground Grid Separation, Grounding Performance, Conductive Coupling, Transferred Potentials, Computer Modeling

1. Introduction

The performance of grounding systems in uniform and two-layer soils has been extensively analyzed in the past decades [1-3]. The study of grounding systems in multilayer soils has recently been the subject of considerable attention by several researchers [4-7]. Analysis of grounding systems buried in hemispherical soils, cylindrical soils and soils containing a number of finite volumes of soil with arbitrary resistivity values has also been carried out in the past few years [8-11]. However, there is no evidence of publicly available literature discussing the feasibility and effectiveness of electrical separation of proximate grounding systems buried in various soil structures, despite the fact that it has been the subject of much heated debate in the past and that it continues to generate much interest and discussion, particularly when the target grounding systems belong to different utilities. Essentially, the main argument used by the advocates of electrical separation is to prevent transfer of high ground potential rise from the neighboring but physically separate grounding system to their own system which is typically a lower voltage installation.

The main objective of this paper is to determine the feasibility and adequacy of electrical separation of grounding systems buried in a variety of soil structures by carrying out a computerized parametric analysis.

The nature of some soil structures sometimes provides strong conductive coupling between grounds, thus preventing an easy electrical separation. It is important to state here that although physical (i.e., geometrical) separation is achieved by keeping a certain distance between grounds, electrical separation (that is dictated by conduction in the soil) will depend heavily on the type of soil structure that exists at the ground site. In some cases, the conductive coupling is rather weak and separation is possible, although in general, one has to make sure that this separation is maintained and monitored over the years, a rather difficult proposition.

2. Reference Case Analysis

The computerized parametric analysis that is described in this section focuses on two identical grounding grids that are buried at a depth of 0.5 m in a two-layer soil. The base or reference case is shown in Figure 1. It consists of two 100m x 50m grids separated by 25 m.

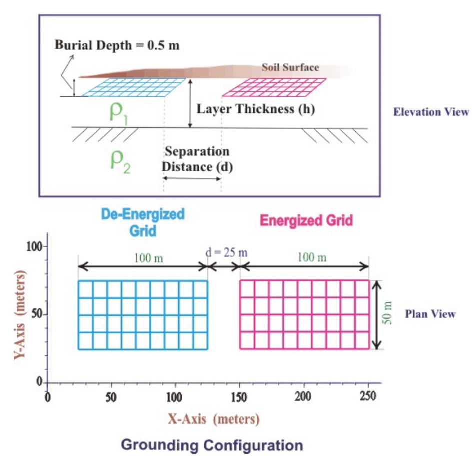

Figure 1. Conductive Coupling between Two Identical Grounding Grids Buried in a Two-Layer Soil.

Three types of soil structures are examined, as shown in Figures 2, 3, and 4. A 100 Ω-m uniform soil, a two-layer soil consisting of a 2 m thick, 10 Ω-m top layer overlying a 1000 Ω-m infinitely thick layer and a two-layer soil similar to the preceding one except for the layer resistivities that are reversed.

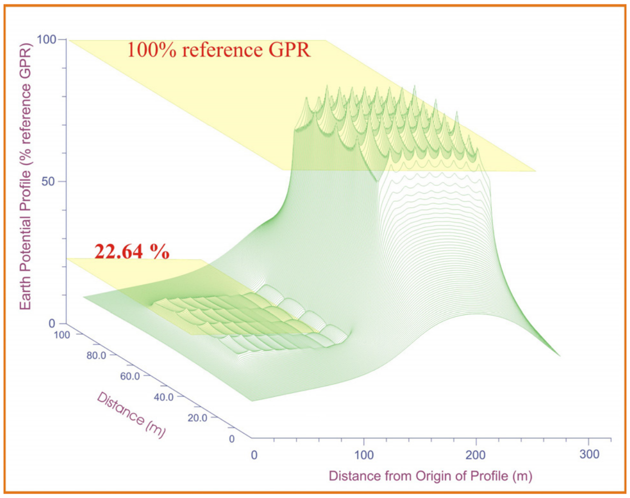

Figure 2. Earth Surface Potentials and Grid GPRs in a Uniform Soil.

The right-hand grid is energized and its GPR (ground potential rise) maintained at a fixed value. This value is used as a reference (100% reference GPR). Figures 2, 3, and 4 show the earth surface potentials that prevail above the grid areas. Note that for clarity, the potential profile axis in Figure 3 starts at 40% instead of 0% as in the other figures. The figures also show the GPR of the non-energized grids due to the transferred potentials through the soil (conductive coupling effects).

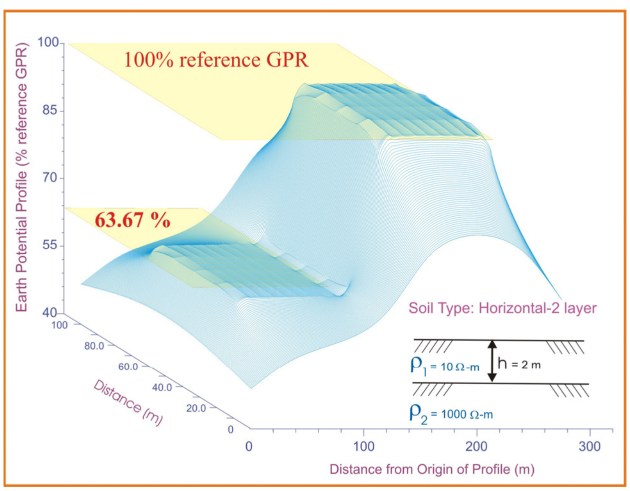

Figure 3. Earth Surface Potentials and Grid GPRs in a Low over High Resistivity Two-Layer Soil Type.

Figures 2 to 4 show clearly that soil structure characteristics have a significant impact on the level of coupling between grounds. For a uniform soil, the coupling factor (ratio) is about 23%. This value increases to almost 64% for a low over high resistivity type of soil, but drops dramatically to almost 1% when the soil is a high over low resistivity two-layer type.

Although these results are remarkable, they are not surprising. Indeed, if we consider the limiting case of an almost metallic top layer soil, we would naturally conclude that a grounding system will transfer almost its entire GPR to any other grounding system that exists in its vicinity. On the other hand, if the bottom semi-infinite soil layer were quasi-metallic then it would impose its remote zero (0%) earth potential to the entire soil except for a narrow rectangular volume of soil extending from the energized grid (where the earth potentials are at about 100% to the bottom layer), which is at 0% potential. In this rectangular volume, the soil potential rapidly decreases from 100% to 0%, as depth increases from 0.5 m (grid depth) to 2 m (beginning of bottom layer). The earth potential just outside this rectangular volume will be essentially at 0% except for some fringing effects, as illustrated in Figure 4.

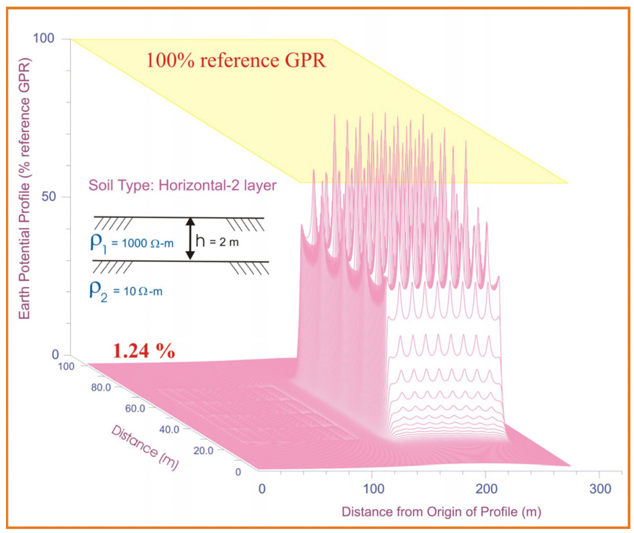

Figure 4. Earth Surface Potentials and Grid GPRs in a High over Low Resistivity Two-Layer Soil Type.

3. Extended Parametric Analysis

In this section the computerized parametric analysis is expanded in order to evaluate the influence of the various parameters that intervene in the performance of grounding systems. These include the layer thickness, layer resistivity contrast ratio (or reflection coefficient), separation distance and grounding grid dimensions. Figure 5 shows the influence of the top layer thickness of a two-layer soil for various contrast ratios of the layer resistivities. The grounding grid corresponds to the reference case. This figure illustrates clearly the wild variations of the coupling factor when these parameters are changed. As expected, the coupling factor approaches the uniform soil value of about 23 % as the layer thickness vanishes or becomes extremely thick compared to the size of the grids. On the other hand, the coupling factor drops from a high value of more than 70% to almost 0%, when the layer thickness is about 5 m, and the resistivity contrast ratio drops from 100 or 0.01 (i.e., k = 0.98 and -0.98, respectively). There is also a rapid change of the coupling factor when the grounding system location moves from one layer to the next (i.e., when the top layer thickness h approaches the grid depth of 0.5 m).

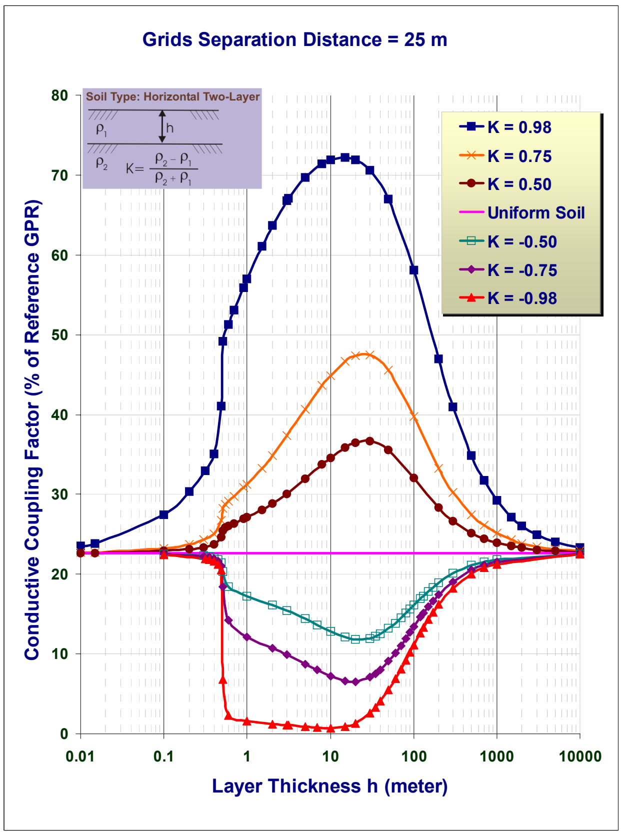

Figure 5. Effects of Layer Thickness and Resistivity Contrast Ratio on the Conductive Coupling Factor.

Figure 6 shows the effects of grid separation on the conductive coupling factor for the three types of soil structures described in Section 2. The results shown in this figure indicates a smooth and gradual decrease of this factor as the spacing increases from a fraction of a meter to about 5 m. Note that for a two-layer soil with a 0.98 reflection coefficient (or $\rho_2/\rho_1 = 100$) the coupling factor reaches almost 100% when the grids are separated by 10 cm while it barely reaches 7 % when this coefficient is -0.98 (i.e., $\rho_2/\rho_1 = 0.01$).

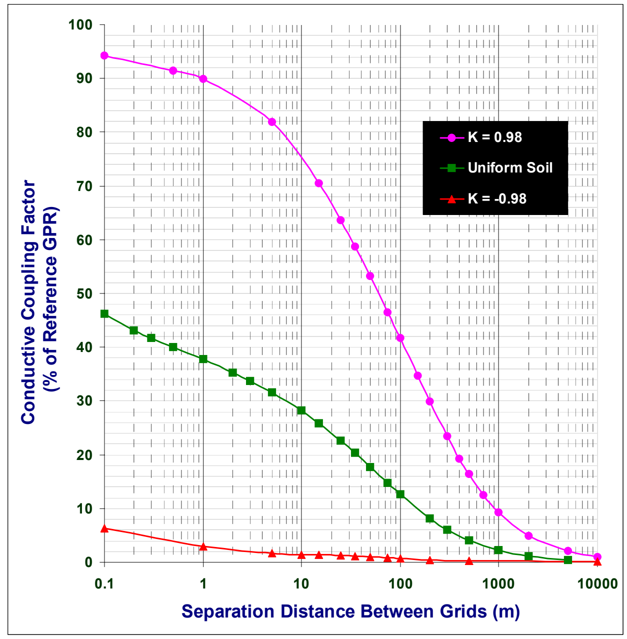

Figure 6. Effects of Separation Distances and Soil Structure on the Conductive Coupling Factor.

Finally, Figure 7 shows the influence of grounding system size on the conductive coupling factor for the soil type structures described in Section 2 and for a separation distance of 25 m. It is obvious that the results shown here are similar to the ones shown in Figure 6. The conductive coupling factor decreases gradually as the grid size decreases, i.e., the grid size compared to the fixed separation distance of 25 m decreases suggesting that the grids are now relatively further apart.

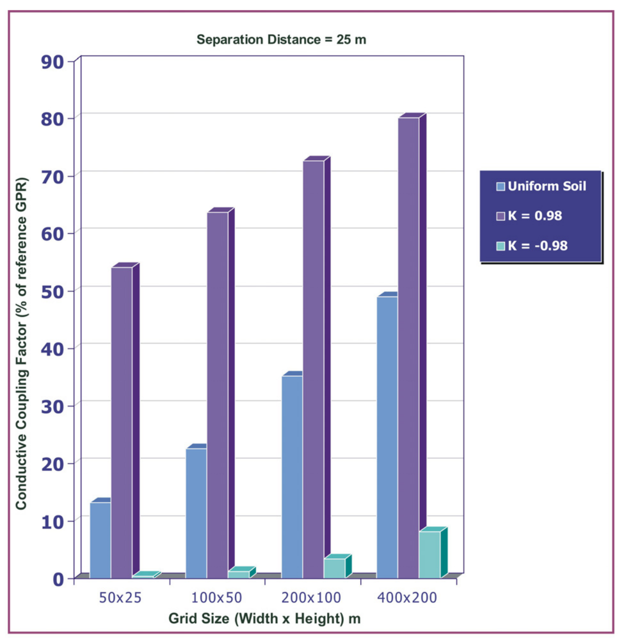

Figure 7. Effects of Grounding System Size and Soil Structure on the Conductive Coupling Factor.

4. Other Types of Soils

In this section we investigate the case of a hemispherical soil structure on the coupling factor. Figure 8 shows the two neighboring grounding grids used in the reference case of Section 2 with the energized grid totally immersed in a hemispherical volume with a resistivity that is 100 times smaller or larger than that of the bulk soil surrounding it.

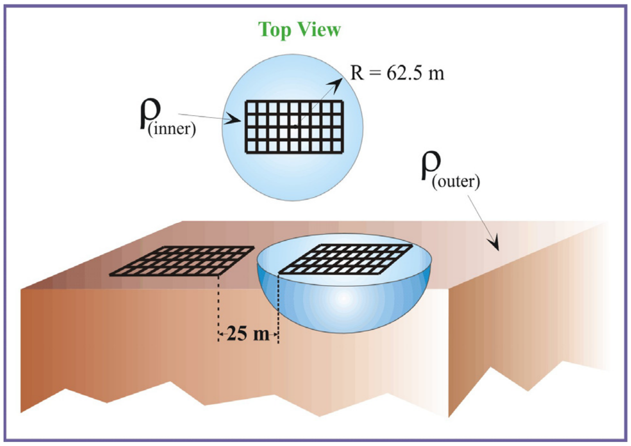

Figure 8. Effects of Hemispherical Soil Structures on the Conductive Coupling Factor.

The results for these two cases are summarized in Table 1. They indicate that the behavior of the grids is similar to the case of a two-layer soil as investigated in the preceding sections, despite the fact that the two grids are physically in two different layers.

Table 1. Hemispherical Soil Computation Results.

Energized Grid & Neighboring Grid: Width = 100 m, Height = 50 m Separation Distance = 25 m	
Hemispherical Soil Structure	**Potential of Neighboring Grid (% of Reference GPR)**
ρ (inner) = 10 Ω-m ρ (outer) = 1000 Ω-m	54.2
ρ (inner) = 1000 Ω-m ρ (outer) = 10 Ω-m	0.39

Based on the results shown above, it is rather clear now that it is not possible to suggest a separation distance that will insure that two independent grounding systems are electrically isolated, without a thorough computer analysis that will determine the effective coupling factor. Failure to conduct such analyses will result in unpredictable and hazardous situations such as those that plagued early computer installations at which isolation of logical (computer) grounds from safety (power) grounds was strongly advocated.

Furthermore, this analysis is by no means exhaustive since it has been restricted to uniform, hemispherical and two-layer soils. There are a large number of other soil types that may reveal other trends for this coupling factor. The study of other types of soil will be the subject of future research work.

5. Conclusions

The feasibility and adequacy of electrical separation of proximate grounding systems buried in a variety of soil structures has been investigated by carrying out a computerized parametric analysis.

The computation results show that the nature of the soil structure has a significant influence on the intensity of the conductive coupling between grounds. Transferred potentials from one system to the other may range from a fraction of one percent to more than 90% in the cases examined. There is also a rapid change of the coupling factor when the grounding system depth moves from one layer to the next. Most of the results shown in this paper have never been published before.

In some cases, the conductive coupling is rather weak and separation is possible, although in general, one has to make sure that this separation is maintained and monitored over the years, a rather difficult proposition. It is not possible to suggest a separation distance that will insure that two independent grounding systems are electrically isolated without a thorough computer analysis that will determine the effective coupling factor.

This paper focused on uniform, hemispherical and two-layer soils. There are a large number of other soil types that may reveal other trends. The study of other types of soil will be the subject of future research work.

6. Acknowledgments

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Biographies

Dr. Farid P. Dawalibi (M'72, SM'82) was born in Lebanon in November 1947. He received a Bachelor of Engineering degree from St. Joseph's University, affiliated with the University of Lyon, and the M.Sc. and Ph.D. degrees from Ecole Polytechnique of the University of Montreal. From 1971 to 1976, he worked as a consulting engineer with the Shawinigan Engineering Company, in Montreal. He worked on numerous projects involving power system analysis and design, railway electrification studies and specialized computer software code development. In 1976, he joined Montel-Sprecher & Schuh, a manufacturer of high voltage equipment in Montreal, as Manager of Technical Services and was involved in power system design, equipment selection and testing for systems ranging from a few to several hundred kV.

In 1979, he founded Safe Engineering Services & technologies, a company specializing in soil effects on power networks. Since then he has been responsible for the engineering activities of the company including the development of computer software related to power system applications.

He is the author of more than one hundred papers on power system grounding, lightning, inductive interference and electromagnetic field analysis. He has written several research reports for CEA and EPRI.

Dr. Dawalibi is a corresponding member of various IEEE Committee Working Groups, and a senior member of the IEEE Power Engineering Society and the Canadian Society for Electrical Engineering. He is a registered Engineer in the Province of Quebec.

Ms. Sharon Tee received the B.Sc. degree in Electrical Engineering from the University of Manitoba in 1990. From 1990 to 1994, she worked as a Business Analyst with Dow Chemical Canada Inc. and was involved in system development, integration and design. From 1995 to 2001, she worked as a technical consultant for Deloitte & Touche Consulting Groups involved in SAP implementation projects for numerous companies.

In May 2001, she joined Safe Engineering Services & technologies ltd., where she is presently working as a scientific researcher and software developer on projects related to AC interference studies, grounding system analysis and software development.

Ms. Tee has coauthored several research reports and papers on system grounding and electromagnetic interference analysis.