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DETERMINATION AN EQUIVALENT GROUND STRUCTURE MODEL ON THE HIGH VOLTAGE SUBSTATION

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Summary: This paper presents a ground structure model determination method. All consideration was done for the real object example. Ground resistivity measurements were made on the high voltage substation. Wenner method was used. Different ground models were created by RESAP software for different substation parts. Different ground models were used to create a different HIFREQ models. By suitable choose of the model most adequate model was selected for future calculations.

Keywords: RESAP, HIFREQ, substation, ground, resistivity, measurements.

1. Introduction

Ground impedance of a power plant grounding system tends to be low. It can be influenced by the following factors:

- size of the grounding system,
- soil resistivity,
- geological structure of the soil (layering),
- test signal frequency.

During lightning grounding system take major part of the lighting current flow assuring that way safety for personnel and electronic devices. Soil resistivity is predominating grounding systems parameters. Grounding extensiveness is constant but ground resistivity depends on seasons, weather conditions and geological structure. Knowledge of the geological structure, ground resistivity change along with depth change can be useful to estimate overvoltages level and to improve substation reliability.
When a grounding system is connected to other one, as is the case for an operating high voltage substation, whose a grounding grid is typically connected to lighting shield wires of the overhead transmission lines or underground cable armor, the effective size of the grounding system is increased. Lighting shield introduce additional inductive coupling problems. Furthermore, since the objective of the research is to create the high voltage substation model, it is desirable to exclude the supplemental grounding provided by the exterior grounding systems. It is very important that the lightning surge frequency spectrum is up to tens of megahertz, so length of a lighting wave is short. Grounding system extensiveness can be limited.
This paper will present influence of the ground resistivity and layering change on the soil model accuracy. All analyzes will be performed for the high voltage substation. There will be also considered ground structure influence on the two and three layer soil model example. Computations were made by RESAP software [1]. All the results can provide better soil model with respect to future HIFREQ [2] calculation results.

2. Analyzed grounding system

The grounding system under test, which consists of a grounding grid made up of FeZn30x4mm (total length 1220m) buried 0,8m deep. For the low voltage cable crossing the grounding system buried 1,45m deep. All connections welded and protected by asphalt glue. The rectangular grid 54m x 44m made of 14 space not equal conductors along the X axis and 4 along the Y axis. Figure 1 illustrates the grounding system adopted for analysis.

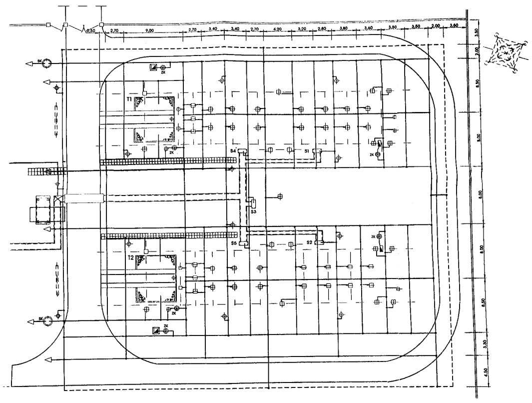

Fig. 1. High voltage substation grounding system

3. Ground resistivity measurements

Soil resistivity measurements were made by injecting current into the earth between two outer electrodes and measuring the resulting voltage between two potential probes placed along a straight line between the current injection electrodes. When the electrodes are close together, the measured soil resistivity is indicative of local surface soil characteristics. When the electrodes are far apart, the measured soil resistivity is indicative of average deep soil characteristics throughout a much larger area. Figure 2 shows a plan view of the soil resistivity measurement arrangement based on the Wenner method.

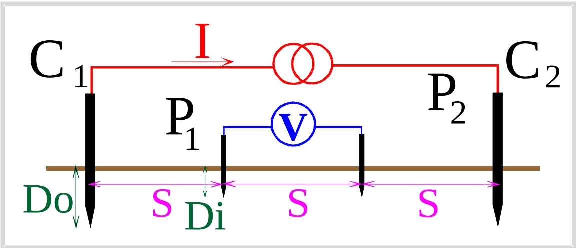

Fig. 2. Soil resistivity measurements - Wenner method

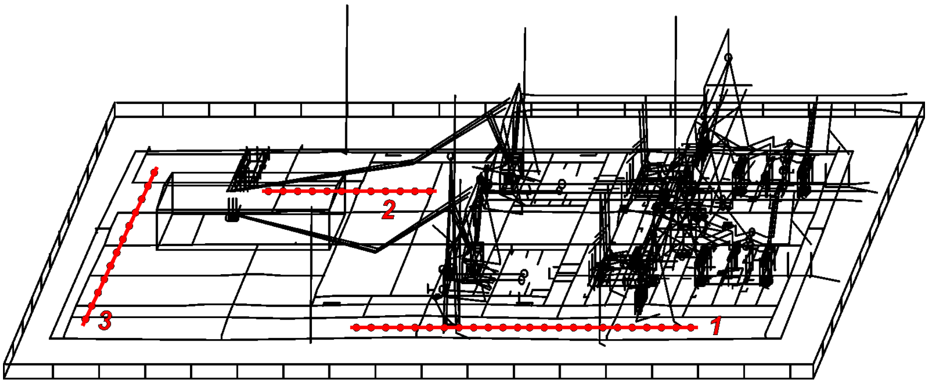

Fig. 3. Soil resistivity measurements traverses

To accurately determine the grounding performance of a substation, it is necessary to carry out resistivity measurements along a traverse (preferably two traverses orthogonal to each other). The largest distance between the two adjacent probes in the Wenner configuration should be ideally at least 3 times (or more) the maximum length of the grounding grid. This will establish a soil structure with a reasonable degree of confidence for the computer analysis [1].

In this case a practical reason limits a maximum length to 28m. Traverses of soil resistivity measurements are presented on figure 3. All measurements were made by the ground resistivity meter AD510. The length of the buried portions of the rods was 8cm according the RESAP recommendation for short spacing. Spacing was constant and equal 10cm.

If energized power lines or associated facilities are present near the measurement site, electrical noise due to load currents will be induced in the potential leads of the resistivity measurement circuits. The magnitude of the induced noise increases with the electrode spacing, while the measured voltage is decreasing. There will be a spacing at which noise constitutes a significant portion of the test voltage. This spacing depends on the angle of the traverse with respect to the power system and on the capacity of the portable generator. This problem can be eliminated by injecting currents at frequencies different from the power line frequency (e.g., 128 Hz) and discriminating between the test current and electric noise using a selective voltmeter build into AD510 [1].

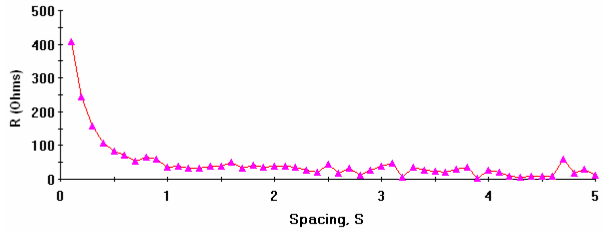

Fig. 4. Soil resistivity measurements results – traverse no. 1

Measurement results are presented on figures 4,5,6 for different traverses respectively. According those measurements results calculations were made by the RESAP software. At the beginning no soil type is requested. RESAP will assume a multi-layer soil structure and automatically determine the appropriate number of layers based on the soil resistivity measurements. The program can produce a soil model which approximates the measured soil resistivity values to the greatest extent possible. By varying the number of layers, the thicknesses of these layers and their resistivity soil model was estimated. It is possible to improve the computed model. For the vast majority of cases involving horizontal soil models, the automated optimization algorithm will choose the proper initial values and derive a reasonable soil model after a single RESAP run [1].

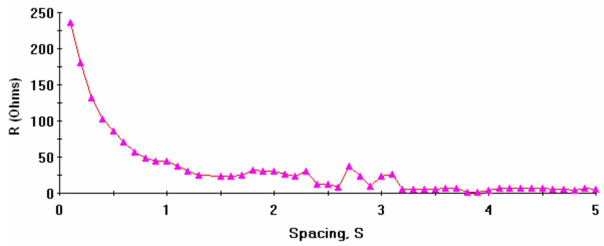

Fig. 5. Soil resistivity measurements results – traverse no. 2

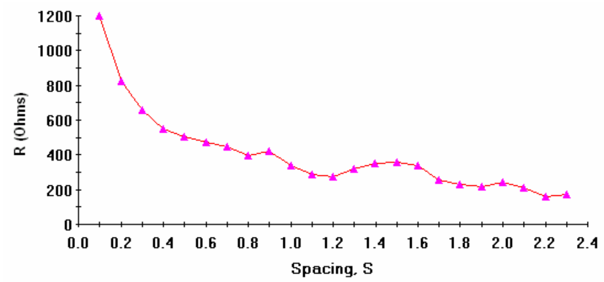

Fig. 6. Soil resistivity measurements results – traverse no. 3

However, there exist some very unusual situations in which user have to intervene in the RESAP interpretation process. For example, after reaching a certain root mean square error (RMS error), the automated interpretation algorithm in RESAP can no longer improve the quality of the curve-fitting because the measured resistivity curve is full of noise, or is not a smooth curve, or exhibit some unphysical features. RMS error is a measure of the dispersion of points around a centre. It is mathematically the spatial equivalent to the standard deviation.

In all these cases, there might be a need to modify data points manually or to provide an initial soil model as the starting point for RESAP to optimize (fig. 7). Occasionally, even with less noisy data, the automated algorithm in RESAP can no longer improve the quality of the fitting after getting the RMS error below a certain value. In this case, locking some soil parameters to user-specified initial values in the SOILTYPE module can help in deriving a better final soil model. In other cases, the user has partial knowledge about the target soil model: for example, for a substation with backfill, the approximate resistivity and thickness of the top layer may be known. In this case, one might want to provide an initial guess of the soil model to RESAP, in order to guide the program in deriving a soil model with top layer characteristics as close as possible to reality [1].

In analyzed case number of measurements points were limited. The first layer resistivity and thickness was locked. RMS error drops from 51% to the 5,91% - traverse number 2. Computation results shows table 1 and 2. Received values seem to be reliable. Soil seems to be wet at top, in the middle dry. Average resistivity which layer no. 4 represents also looks fine for sand area nearby the HV substation.

Table 1. Layer characteristics for traverse no.2 before optimization

Layer	**Resistivity**	**Thickness**	**Coefficient**	**Contrast**
Number	(ohm-m)	[m]	[p.u.]	Ratio
1	infinite	infinite	0.0	1.0
2	199.2175	0.2754413	-1.0000	0.19922E-17
3	415.1285	1.015175	0.35145	2.0838
4	22.84636	infinite	-0.89567	0.55034E-01

Table 2. Layer characteristics for traverse no.2 after optimization

Layer	**Resistivity**	**Thickness**	**Coefficient**	**Contrast**
Number	(ohm-m)	[m]	[p.u.]	Ratio
1	infinite	infinite	0.0	1.0
2	165.3243	0.1033122	-1.0000	0.16532E-17
3	394.7320	0.2303869	0.40962	2.3876
4	204.3552	infinite	-0.31778	0.51771

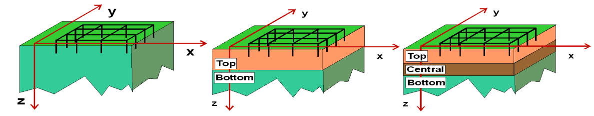

Fig. 7. Soil types – a) uniform, b) 2 layers, c) 3 layers.

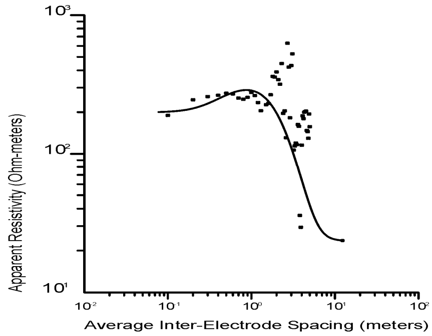

Fig. 8. Calculation results for traverse no. 2 - before optimization

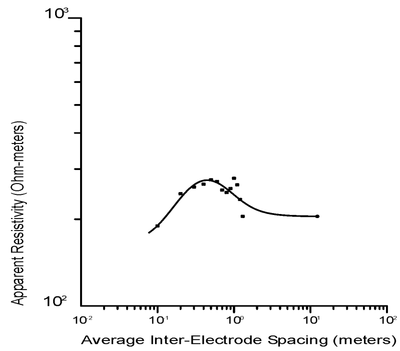

Fig. 9. Calculation results for traverse no. 2 – after optimization

4. Conculsions

This paper presented determination an equivalent ground structure for HV substation. Measurements and calculation allows this approximation with good accuracy. RESAP software used for calculations has got same limitations. More than one soil model can produce similar apparent resistivity measurement curves. Sometimes RESAP can suggest extreme resistivity values. Proposed methods should improve quality of the approximation. Received soil types will be used for future calculation in the HIFREQ software [3].

5. References

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