# 1. EQUIVALENT MULTILAYER VS MULTIREGION SOIL MODEL

As is well known, in very large grounding systems, soil resistivity varies both vertically and horizontally.
In these cases, resistivity measurements are usually performed on different regions of the system.
Mixing all measurements to obtain an equivalent multilayer model is a reprehensible practice, as this loses valuable information relating to the locations where the measurements were taken.
The following illustrates the results obtained using the equivalent multilayer soil model and the multiregion model.
The multiregion model keeps the multilayer models obtained from resistivity measurements in different regions separate and uses the information relating to the locations where the measurements were taken.

The grounding system used in this cases study is quite large (maximum size about 500 m), but obviously in reality much more extensive systems can be found.
The system is energized with a current to earth injected in a specific point.

Grounding system and injected current input data:

- Frequency = 50 Hz
- $I_e$ = 40 A ∟0.0°
- Depth of grid burial = 0.7 m
- Wires diameter = 8.9 mm
- Wires cross section = 50 $mm^2$ (solid)
- Wires material: copper (resistivity 1.8*$10^{-8}$ Ωm, relative permittivity 1, relative permeability 1)
- Layout: see the following figure

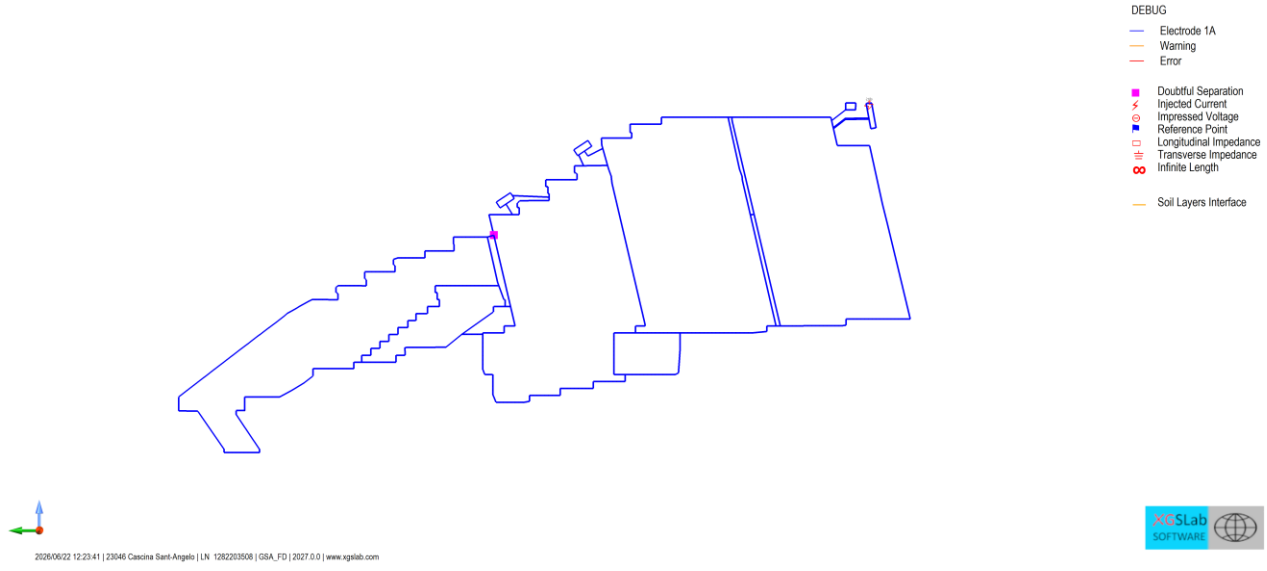



*Figure 1-1: Grounding system layout*

The soil resistivity measurements have been performed in three specific regions.
The measured apparent soil resistivity as a function of the electrodes spacing value is indicated in the following Figures.

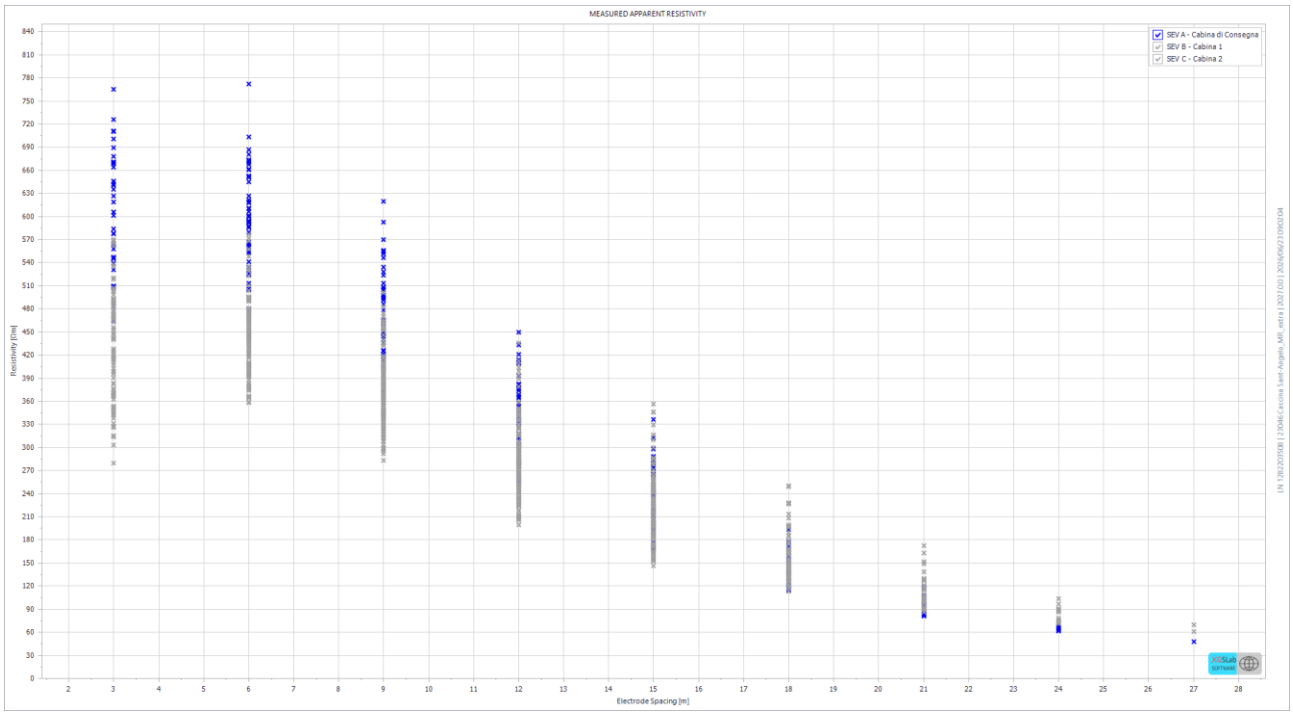



*Figure 1-2: Measured apparent soil resistivity as a function of the electrodes spacing – Region 1*

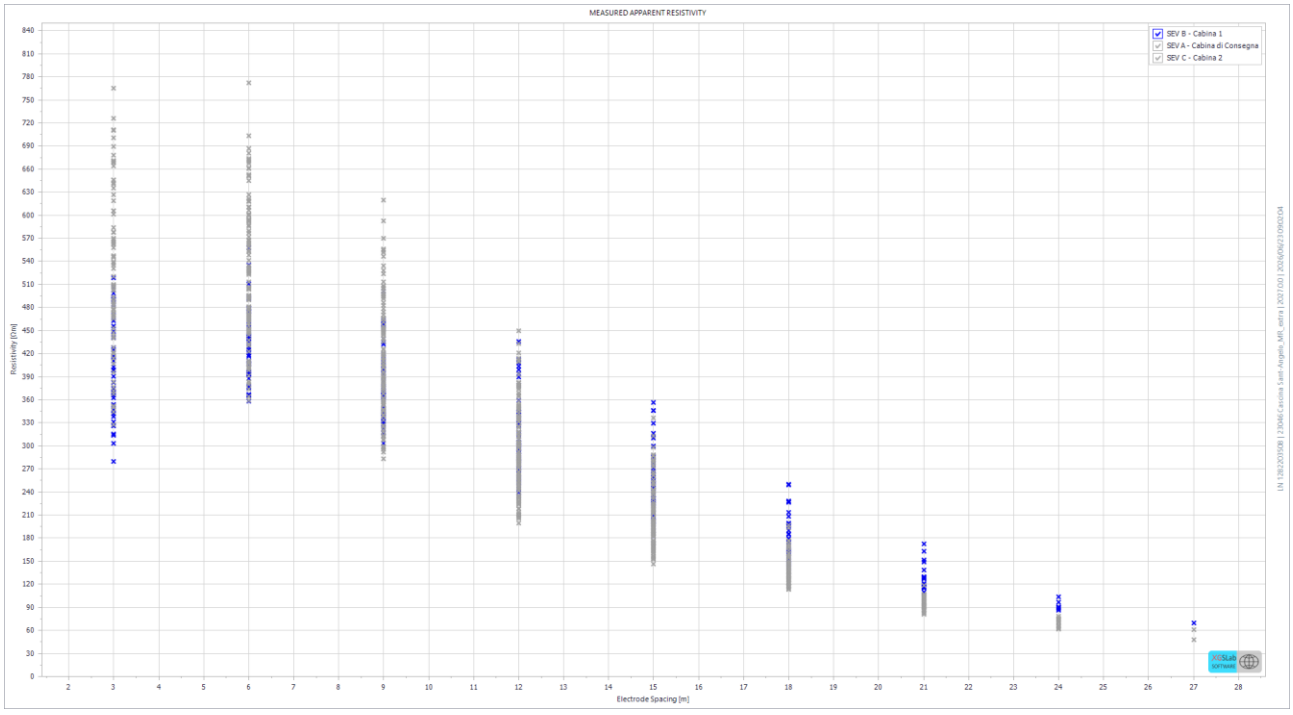



*Figure 1-3: Measured apparent soil resistivity as a function of the electrodes spacing – Region 2*

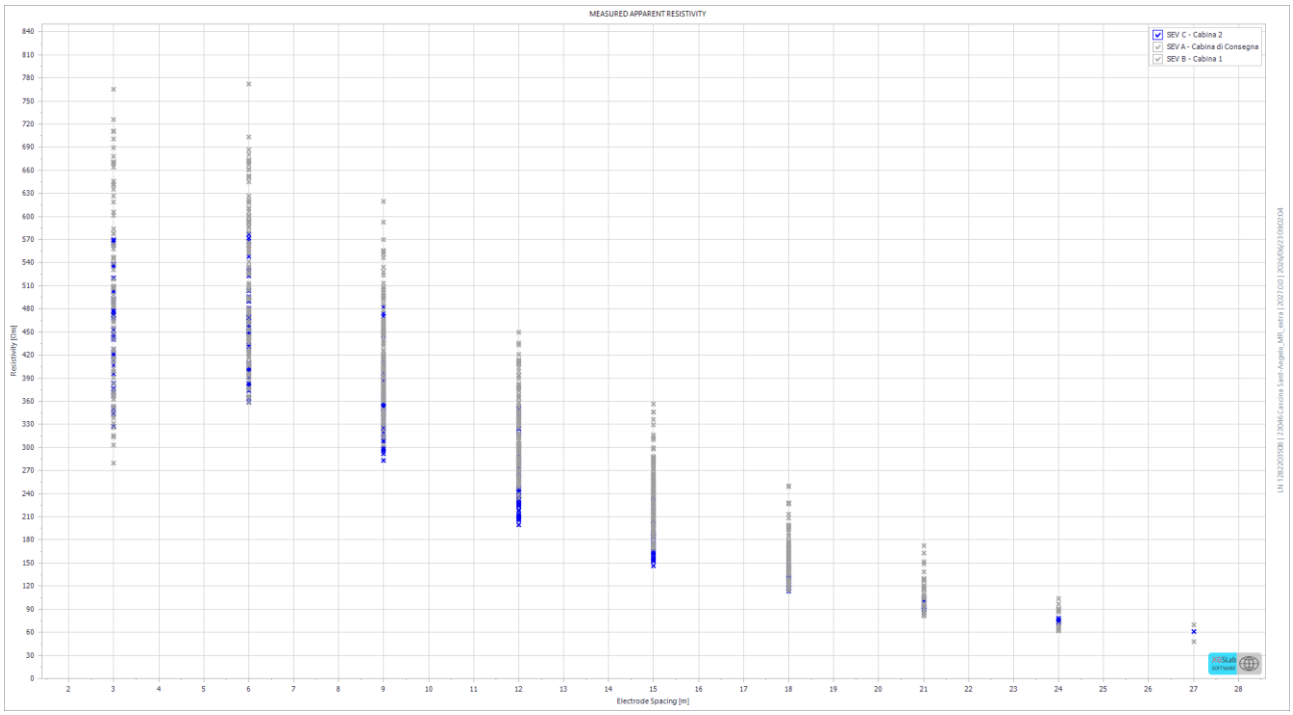



*Figure 1-4: Measured apparent soil resistivity as a function of the electrodes spacing – Region 3*

With the values in previous Figures and the following calculation settings:

1) "Layers Number = Automatic"
2) "Average = None" (default setting)
3) "Constraints range = Default" (default setting)
4) Flag "Weights = Checked" (default setting)
5) "Initial, Lower and "Upper" default values

the parameters calculated by SRA are as indicated in the following Table.

| | Region A | Region B | Region C | Equivalent |
|---|---|---|---|---|
| $\rho_1$ (Ωm) | 451.07 | 167.71 | 131.22 | 495.27 |
| $\rho_2$ (Ωm) | 1534.76 | 687.43 | 1808.96 | 11.75 |
| $\rho_3$ (Ωm) | 20.38 | 23.77 | 41.363 | - |
| $\rho_4$ (Ωm) | - | - | - | - |
| $\rho_5$ (Ωm) | - | - | - | - |
| $h_1$ (m) | 2.042 | 0.92 | 0.751 | 9.172 |
| $h_2$ (m) | 2.547 | 5.56 | 1.78 | - |
| $h_3$ (m) | - | - | - | - |
| $h_4$ (m) | - | - | - | - |
| RMS Error % | 8.48 | 11.35 | 9.62 | 16.95 |

*Table 1-1: Soil model parameters calculated by SRA and related RMS error*

Note that the error in the equivalent model is much larger than the error in the region-based models. The multiregion soil model calculates the individual models more precisely and also retains valuable information about the location of the measurements.

In all cases:

- Soil relative permittivity = 6
- Soil parameters dependence: Independent

The measured resistance to earth related to Region 1 location = 0.25 Ω.

Using the equivalent multilayer soil model, the resistance to earth related to Region 1 location = 0.46 Ω.
The main results are the following:

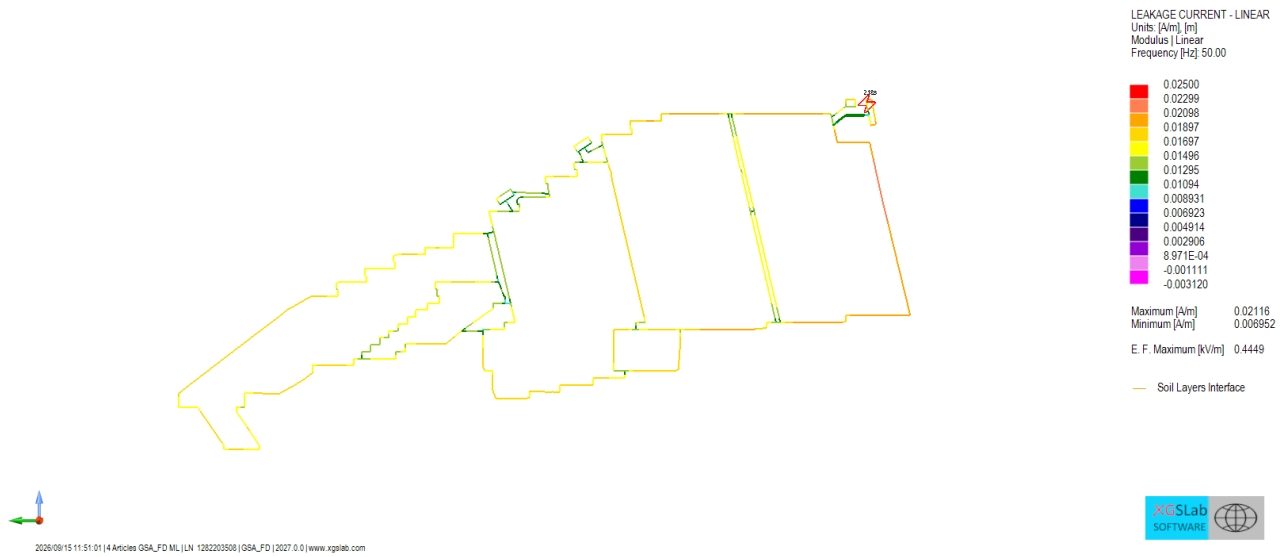



*Figure 1-5: Leakage current distribution with the equivalent multilayer soil model*

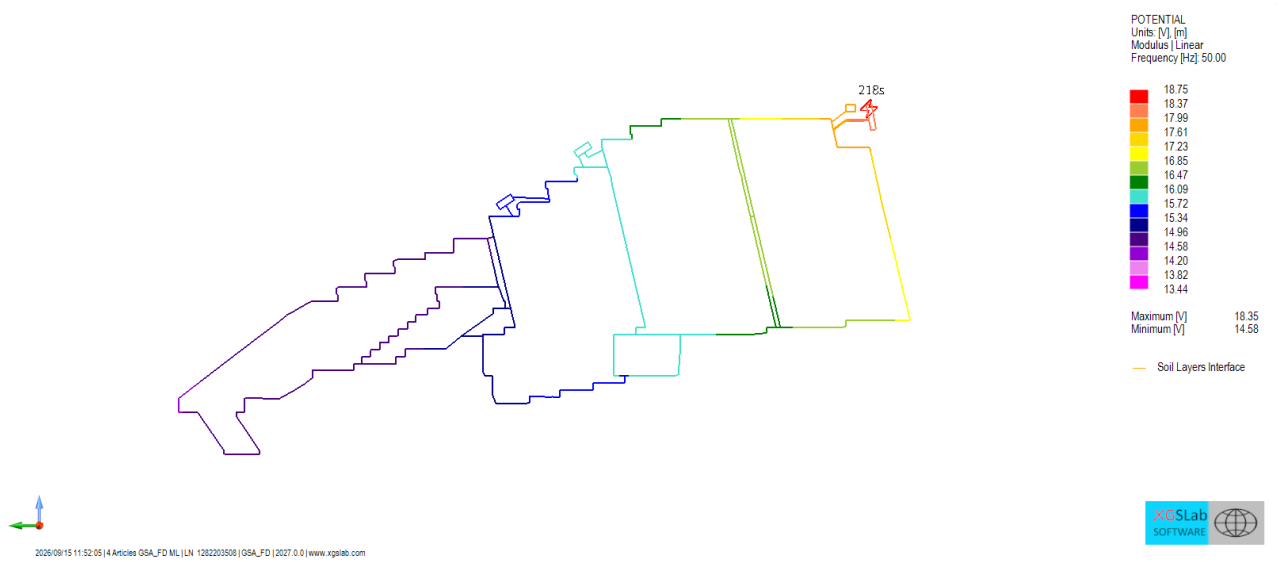



*Figure 1-6: Potential distribution with the equivalent multilayer soil model*

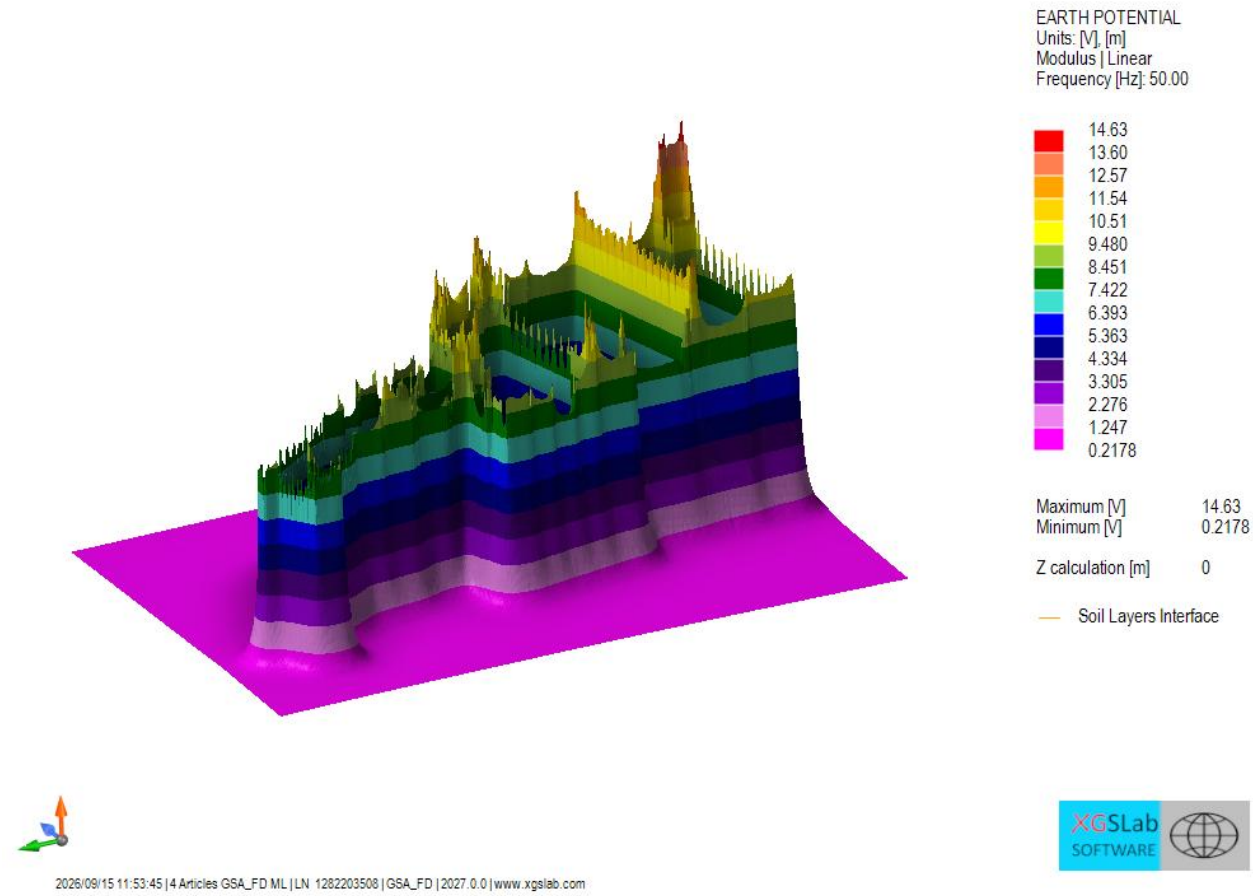



*Figure 1-7: Earth surface potential distribution with the equivalent multilayer soil model*

Using the multiregion soil model the resistance to earth related to Region 1 location = 0.386 Ω.
The main results are the following:

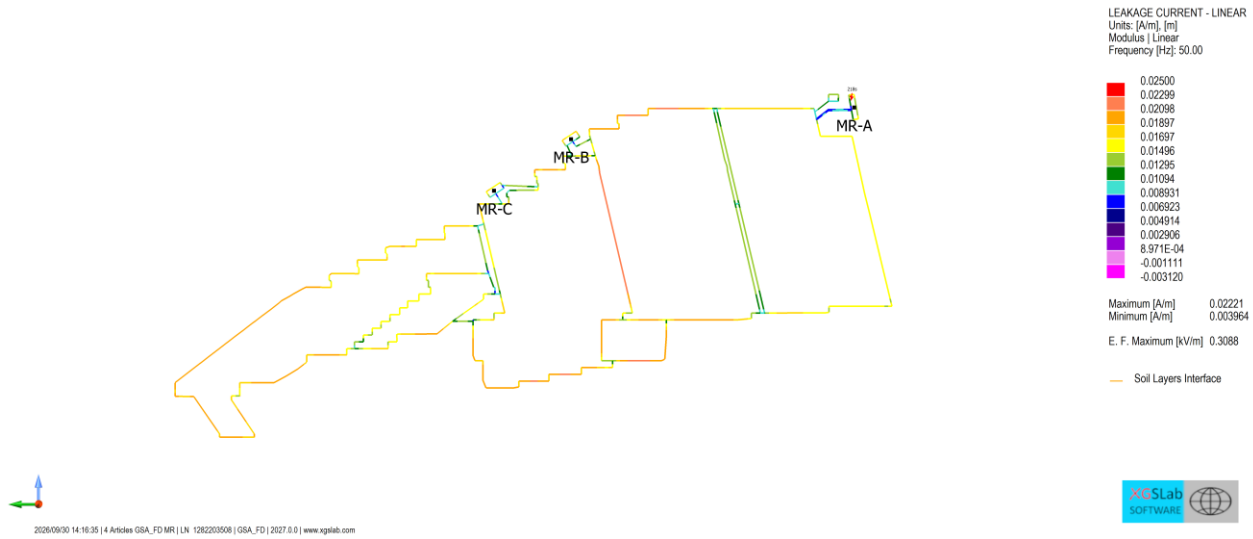



*Figure 1-8: Leakage current distribution with the multiregion soil model*

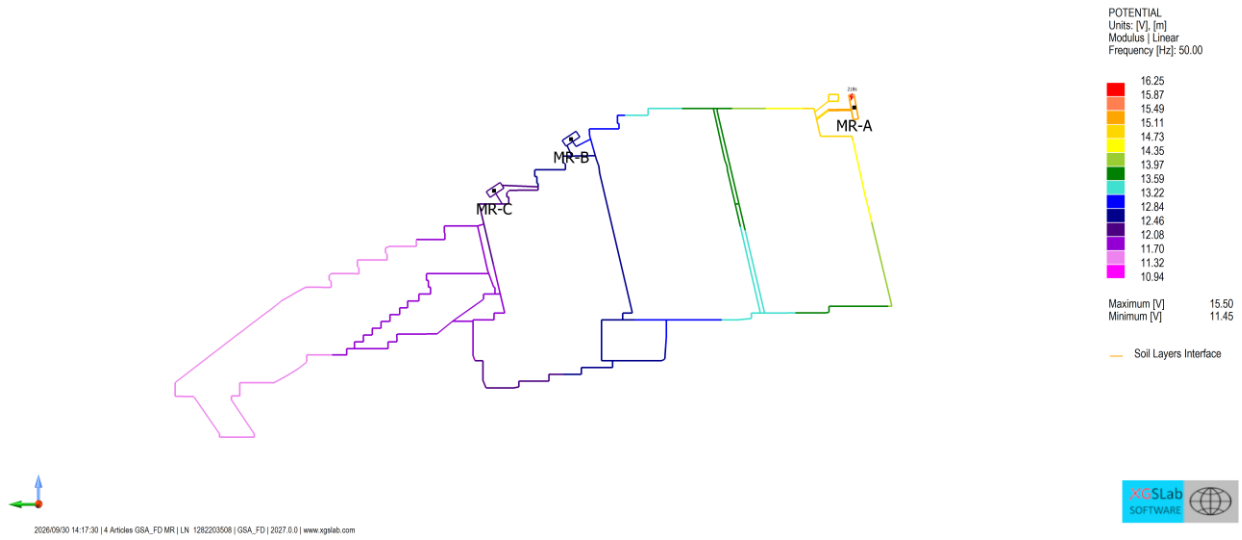



*Figure 1-9: Potential distribution with the multiregion soil model*

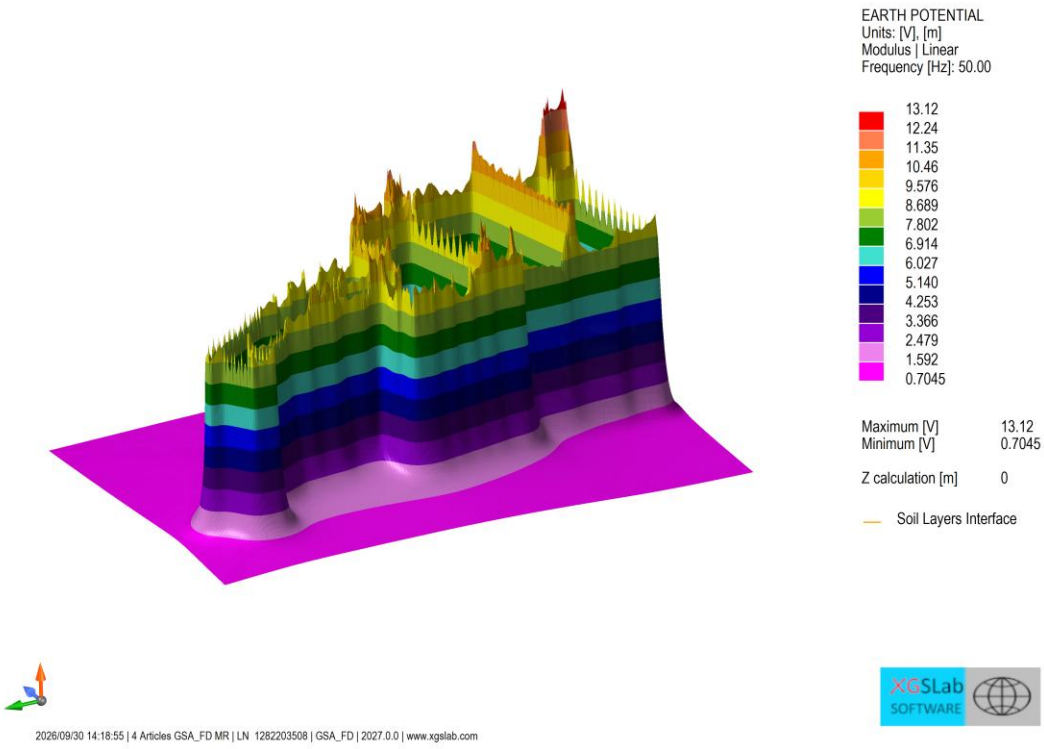



*Figure 1-10: Earth surface potential distribution with the multiregion soil model*

Using the multiregion soil model and including in the simulations the existing metallic structures acting as natural earth electrodes (essentially the foundation of the PV panel structures), the resistance to earth related to Region 1 location = 0.229 Ω.

The main results are the following:

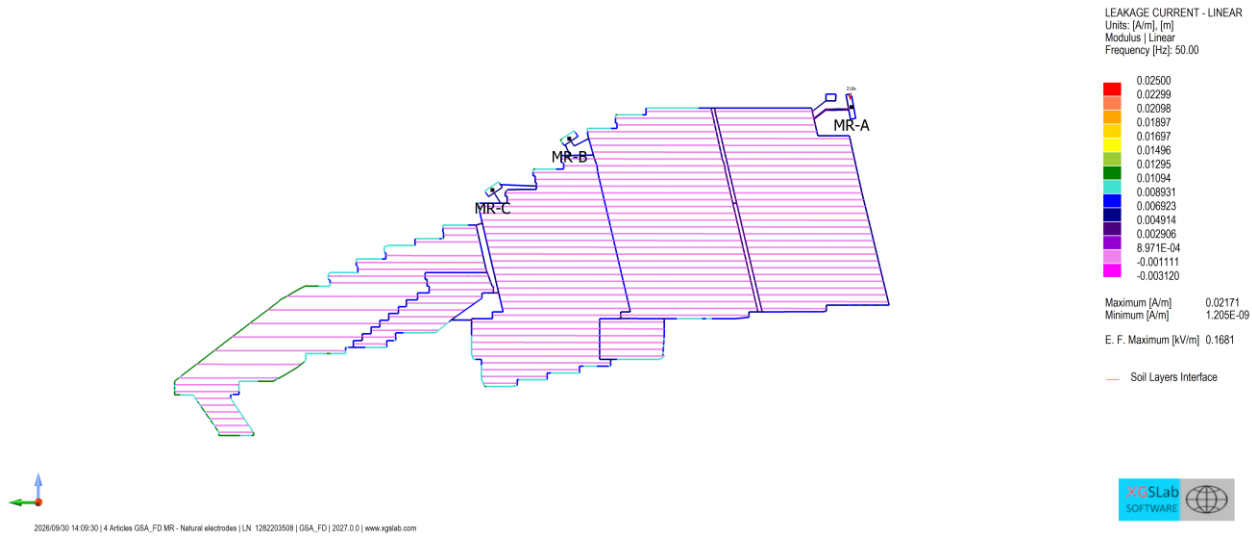



*Figure 1-11: Leakage current distribution with the multiregion soil model + natural earth electrodes*

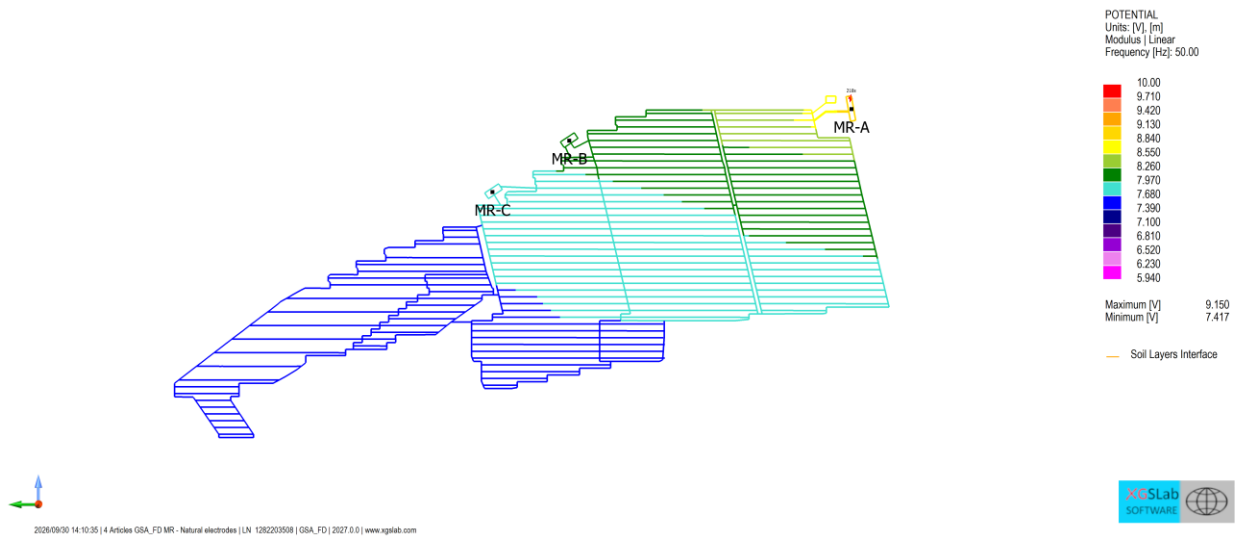



*Figure 1-12: Potential distribution with the multiregion soil model + natural earth electrodes*

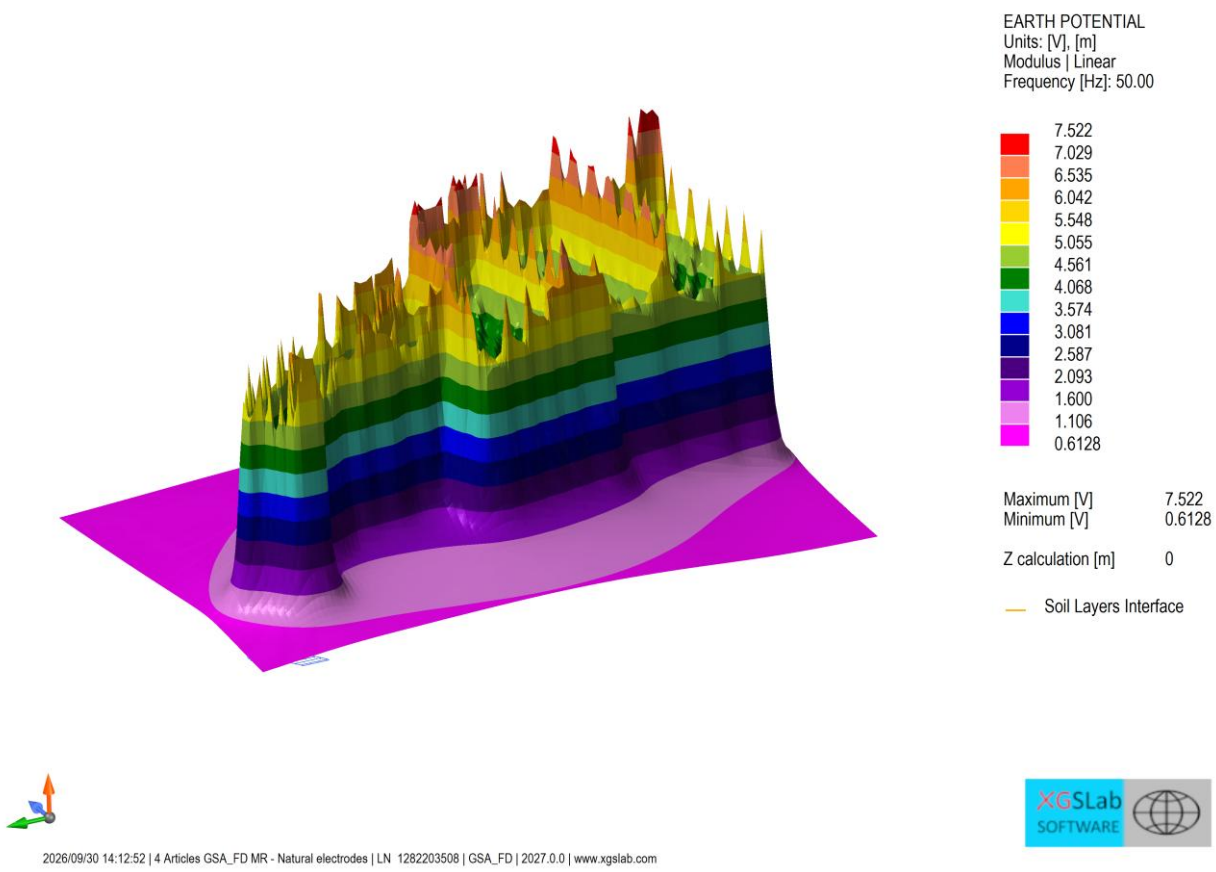



*Figure 1-13: Earth surface potential distribution with the multiregion soil model + natural earth electrodes*

As a general comment, note how the multiregion model produces results more consistent with those expected. For example, leakage currents are higher where resistivities are lower. In this specific case, the difference between resistivities in the different regions is not very high, but even in this relatively "easy" case, the multiregion model highlights great potential and a greater adherence between simulations and reality.

In any case, it is clear that simulating the real situation (multiregion + natural earth electrodes) produces results very similar to the measured values. In these comparisons, it is essential that the measurements are performed with care and professionalism, something beyond our control. If the measurements are reliable, this comparison can be used as validation.