SINT Srl

ONE STEP AHEAD

XGSLab™

THE STATE OF THE ART OF THE
ELECTROMAGNETIC SIMULATION FOR
POWER, GROUNDING AND
LIGHTNING PROTECTION SYSTEMS

XGSLab™ Vs. CDEGS®
CALCULATION MODELS

[September 2019]

Introduction

The program XGSLab includes the following modules based on the field theory:

- GSA (Grounding System Analysis)
- GSA_FD (Grounding System Analysis in the Frequency Domain)
- XGSA_FD (over and under Ground System Analysis in the Frequency Domain)
- XGSA_TD (over and under Ground System Analysis in the Time Domain)

The program CDEGS® (developed by SES & Technologies ltd. Canada) includes many modules and in particular:

- MALT®
- MALZ®
- HIFREQ®

The different modules are based on different physical assumptions and each of them has a specific application range (detailed description of the different modules are here omitted).
The comparison was made between modules based on similar assumptions.
The following table summarizes the main assumptions on which the different modules of XGSLab are based:

Aspects taken into account	GSA	GSA_FD	XGSA_FD
Resistive coupling	Yes	Yes	Yes
Capacitive coupling	No	Yes	Yes
Self-Impedance	No	Yes	Yes
Mutual Impedance (inductive coupling)	No	Yes	Yes
Soil parameters	ρ	ρ, $\varepsilon = f(\omega)$	ρ, $\varepsilon = f(\omega)$
Propagation law	1/r	$e^{-\Upsilon r}/r$	$e^{-\Upsilon r}/r$

Table 1: Aspects taken into account by the different modules

XGSA_TD is based on the so called "frequency domain approach". As known, a transient can be considered as the superposition of many single frequency waveform calculated with the forward Fourier transform. Using the frequency domain model implemented in XGSA_FD it is then possible calculate a response for each of these single frequency waveform. The resulting time domain response can be obtained by applying the inverse Fourier transform to all these response.

GSA has been compared with MALT®.
The modules GSA and MALT® are based on the fundamental assumption that each electrode is equipotential and neglect both the self and mutual impedances among conductors and the attenuation effects. For these reasons, these modules can be applied only when the electrode size is much smaller than the wavelength of the electromagnetic field in the earth.

GSA_FD has been compared with HIFREQ® and MALZ®.
The modules GSA_FD and HIFREQ® take into account the effects of both the self and mutual impedances among conductors and the attenuation effects and can be applied in general conditions (full-wave models).
HIFREQ® can consider different accuracy levels, depending on the parameter settings. The Default setting adopts a low frequency approximation while the Medium and High settings are more precise but require more calculation time.

In the following, only High and Default accuracy levels are taken into account.

The module MALZ® takes into account the voltage drop along conductors due to their self-impedance but it does not consider the effects of mutual impedance among conductors and the attenuation effects and for this reason in some circumstance can be affected by inaccuracy in results. Essentially MALZ® is not based on a full-wave model. Moreover MALZ® does not consider the soil relative permittivity.

In all cases the comparisons has been make taking into account a large meshed grid (500 m x 500 m) as a case of study.

CDEGS® results are available online in the free document "Comparison of Low-Frequency and High-Frequency Grounding Software Package Capabilities".

Main input data:

- I_E = 1000 A (phase 0 deg) injected in a grid corner
- Frequency = 60 Hz
- Low frequency soil resistivity = 1, 2, 5, 10, 20, 50, 100, 200, 500, 1000, 10000 Ωm
- High frequency soil relative permittivity = 1
- Soil parameters frequency dependence: Independent
- Depth of grid burial = 0.5 m
- Wires Cross Section = AWG 4/0 (107.22 mm^2)
- Wires diameter = 13,41 mm
- Wires material: copper (resistivity 1.8*10^{-8} Ωm, relative permittivity 1, relative permeability 1)
- Grid dimension: 500 x 500 m
- Grid mesh: 25 x 25 m
- GPR reference point: injection point
- Layout: see Figure 1

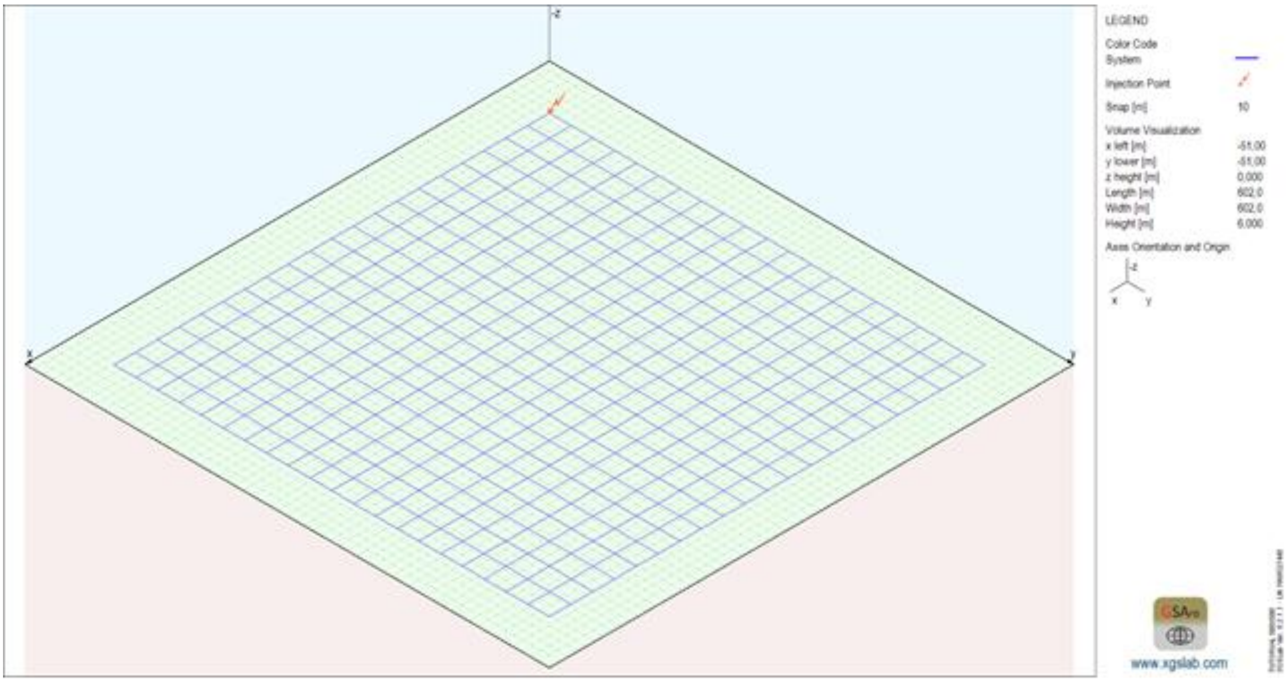

Figure 1: "Grounding System Layout" 3D representation

Comparison between GSA and MALT®

The comparison between the values of Ground Potential Rise (GPR) obtained using GSA and MALT® is represented in Figure 2.

The maximum difference between the results obtained with GSA and MALT® is lower than 0.05 % and for this reason, the results in Figure 2 are overlapped and indistinguishable.

The agreement between the results obtained with XGSLab and CDEGS® is excellent with any resistivity value (for practical purposes results are the same).

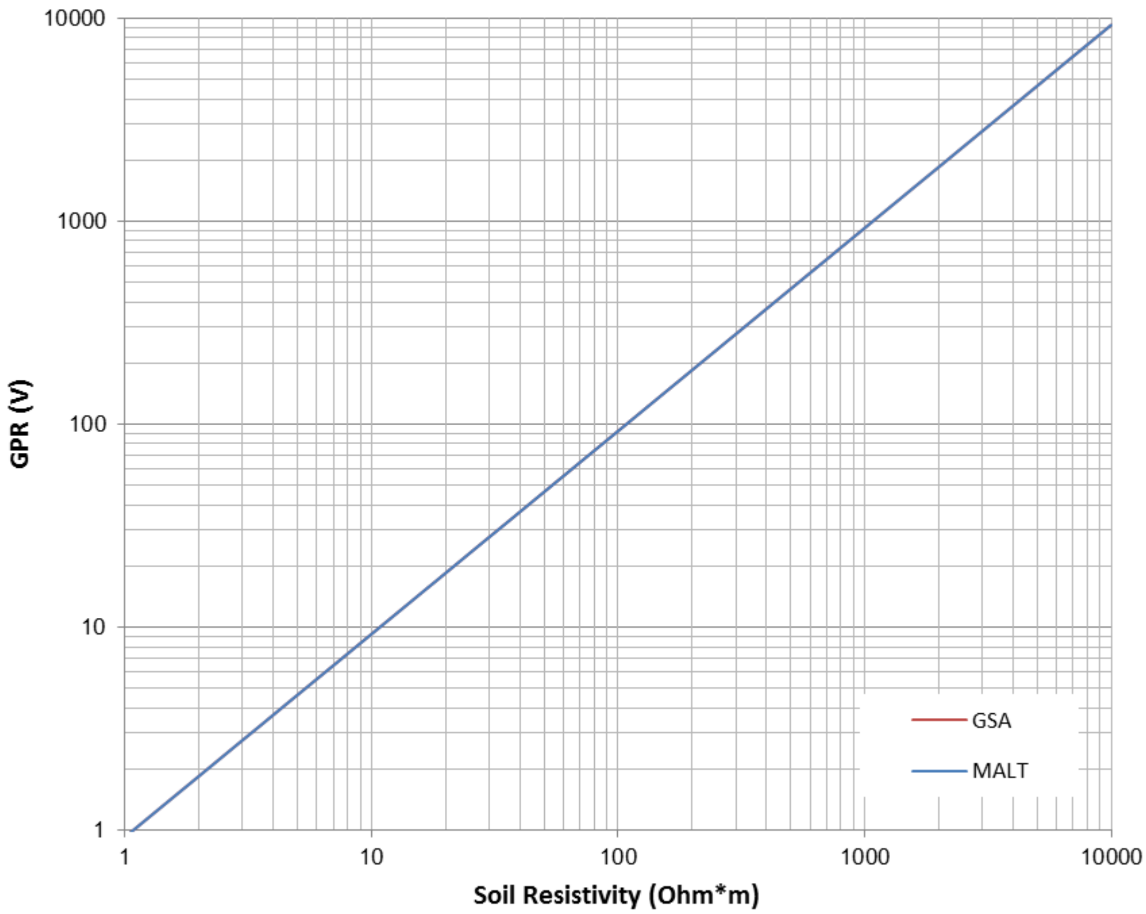

Figure 2: Comparison between GSA and MALT®

Comparison between GSA_FD, HIFREQ® and MALZ®

The comparisons between the values of Ground Potential Rise (GPR) obtained using GSA_FD, HIFREQ® and MALZ® are represented in Figure 3 and Figure 4.
Figure 3 includes all results.
Figure 4 gives details about the comparison between GSA_FD and HIFREQ® with high and default sets of accuracy settings.

The agreement between the results obtained with XGSLab and CDEGS® is excellent over the full test range in particular with HIFREQ® High precision version. The same results has been obtained with with relative permittivity = 6.

The maximum differences between the results obtained with GSA_FD and HIFREQ® High are -0.65 % and +0.64% with soil resistivity values higher 5 and 100 Ωm respectively.
Then, differences between results are very small and for this reason, the results with GSA_FD and HIFREQ® High in Figure 3 are overlapped and indistinguishable.

Results with HIFREQ® Default precision are affected by errors up to 10% in the soil resistivity range 10 - 100 Ωm.
Results with MALZ® are affected by errors also over 20% in the soil resistivity range 10 - 100 Ωm.
Then, using approximations in calculations, the errors are relevant in soil resistivity range most usual.

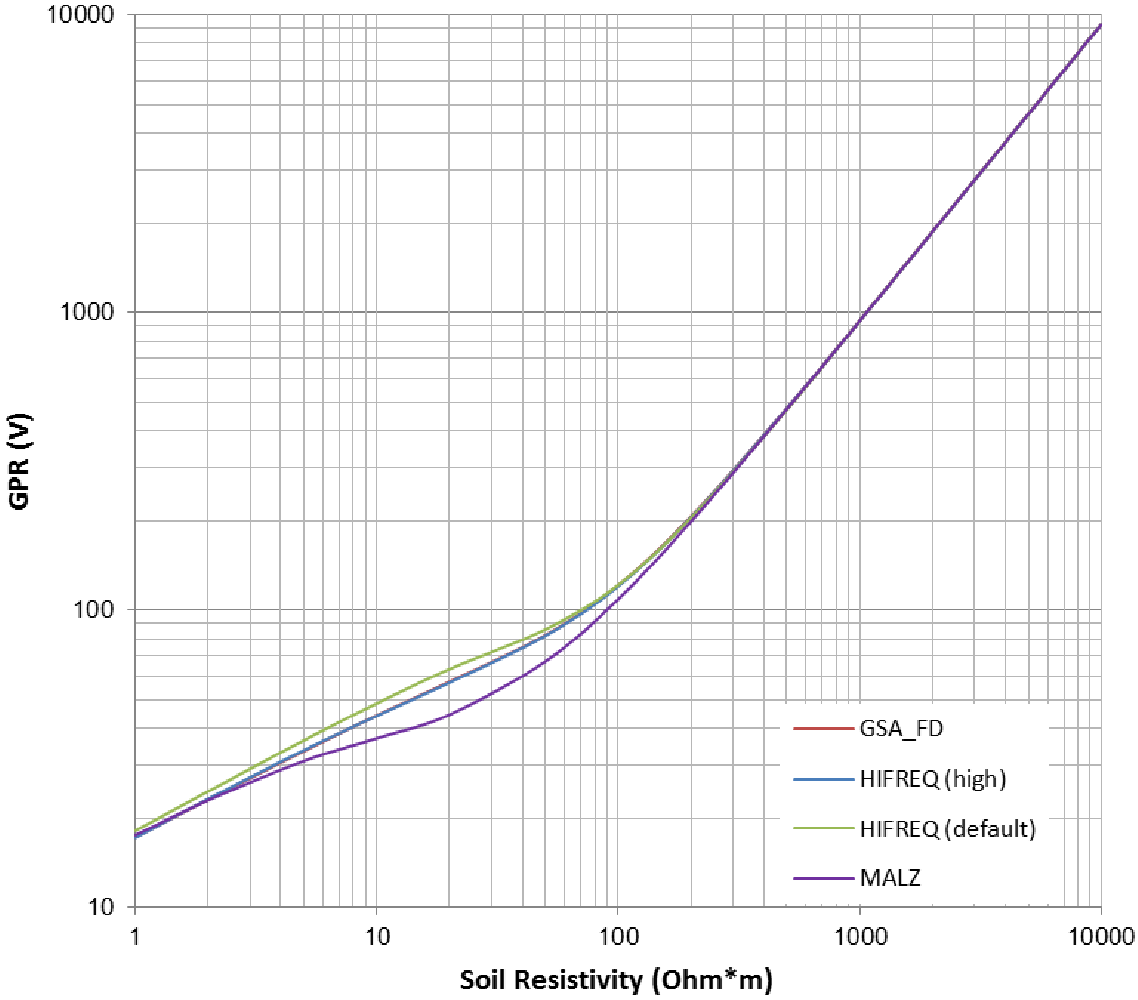

Figure 3: Comparison between GSA_FD, HIFREQ® and MALZ®

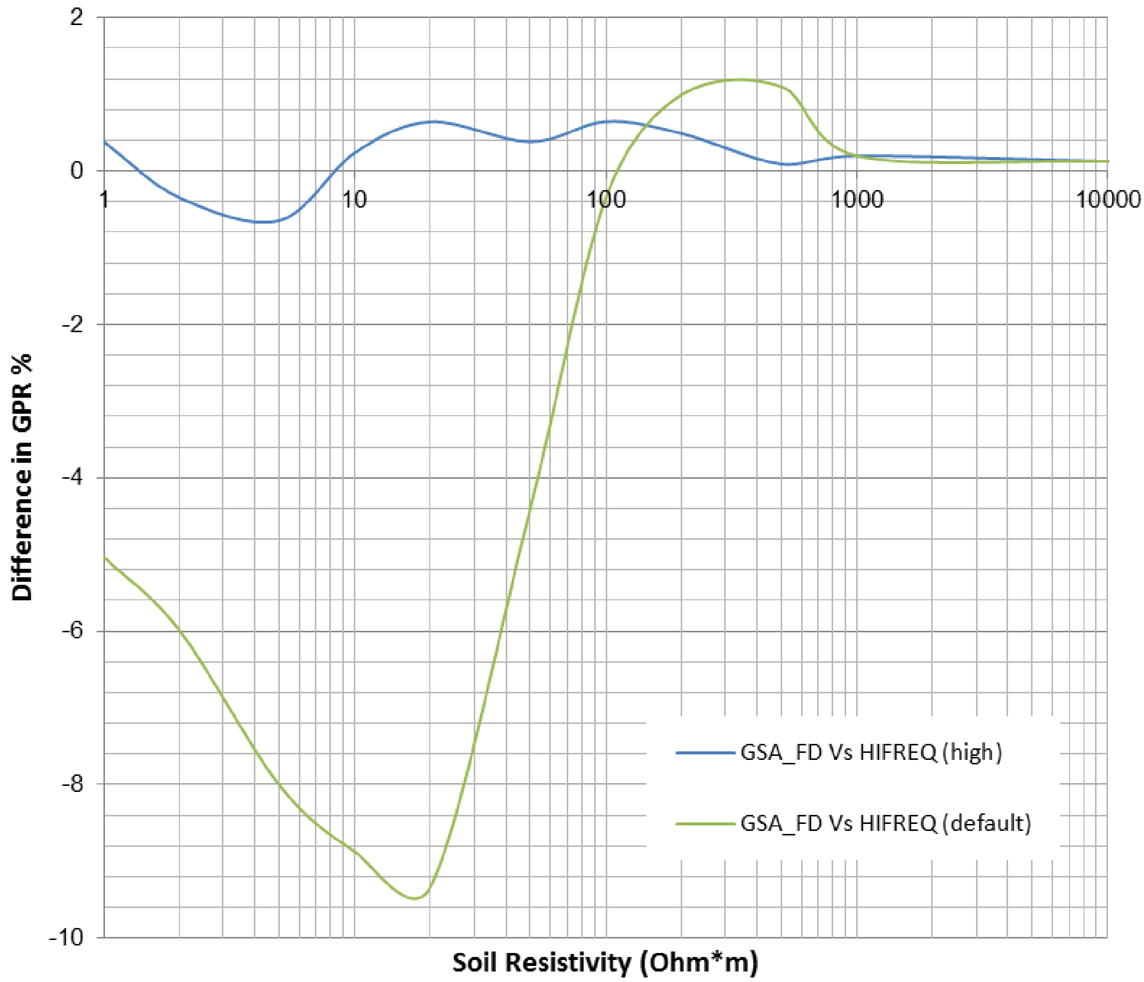

Figure 4: Difference in GPR results GSA_FD and HIFREQ®