SINT Srl

ONE STEP AHEAD

XGSLab™

SCIENCE FOR ENGINEERING

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

FAQ

ELECTROMAGNETIC SIMULATION FOR
POWER SYSTEMS, GROUNDING, INTERFERENCE AND LIGHTNING

1995 – 2023
(Release 10.3.1 - 06/23)

FAQ

(Frequently Asked Questions)

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REVISION RECORD

Date	Release	Note
October 2012	4.0.1	New module GSA
September 2014	5.0.1	New module GSA_FD
March 2015	6.0.1	New module XGSA_FD
March 2017	7.0.1	New module XGSA_TD
July 2017	8.0.1	Multilayer Soil Model
November 2017	8.1.1	IEC Standard
February 2018	8.2.1	Low Frequency Breakdown Solution + Draw Tools
April 2018	8.3.1	Higher Robustness Calculation Algorithms + Graphical Outputs
January 2019	8.3.2	General improvements + New module NETS predisposition
February 2019	9.0.1	New module NETS
June 2019	9.1.1	Zig-Zag Transformer + Pipe Type Cable + Fragmentation Rules
September 2019	9.2.1	XGSA_TD extended to 100 MHz + Corona Effect Tool
November 2019	9.3.1	General improvements
March 2020	9.4.1	Increasing in computing speed + Imperial Units
July 2020	9.5.1	Seasonal Analysis + Export to Google Earth™
February 2021	9.6.1	Libraries refactoring + New viewer based on OpenGL
September 2021	10.0.1	New module SHIELD + New CAD based on OpenGL
May 2022	10.1.1	Screened Conductors + Multicores Cables
December 2022	10.2.1	New Scheduling Tool + Unlimited Elements number
June 2023	10.3.1	Electromagnetic Forces + Surge Protective Devices

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1. SALES

1.1 ARE TRAINING COURSE AVAILABLE FOR XGSLAB?

Training course are for XGSLab Clients only and usually Web-Based.
We are working to a complete certified training course path (XGSLab ACADEMY) divided in 3 levels:
Level 1: Preliminary + Grounding + Fault Current Distribution (already available)
Level 2: Electromagnetic Interference and Fields + Lightning and Transients + Lightning Shielding
Level 3: Advanced Applications and Knowledge
Each course will be divided in modular sessions.
Web-based courses are usually appreciated by customers because effective and cheap.
Furthermore you can count on a complete and clear User’s Guide with some very useful Tutorials and Videos.

1.2 IS XGSLAB AVAILABLE AS ANNUAL SUBSCRIPTION?

XGSLab is available as formally Perpetual license (10 years after last support expiration date) and as Annual Subscription. In the future the Annual Subscription will be the preferred license form.

1.3 DOES XGSLAB INCLUDES A SUPPORT AND MAINTENANCE SERVICE?

XGSLab includes 12 months of support period.
Support service includes software update and maintenance support and Regular Engineering Applications support.
Software update and maintenance support includes new release, software patches and installation support.
Regular Engineering Applications support includes advice on how best to apply XGSLab to specific engineering problem.
Support requests are normally processed within 24 hours. Support is not available on Saturday and Sunday and during local National holydays. Moreover, Support will be limited during the Christmas period and the two central weeks of August due to Summer holydays.
Support requests must be addressed to “support@xgslab.com”.

The support period may be renewed on an annual basis for periods of 1, 2 or 3 years.
Support is included in Annual Subscriptions during the validity period.

1.4 WHAT ARE THE HARDWARE AND SOFTWARE REQUIREMENTS?

XGSLab is designed to operate on a personal computer (PC) having the following software and hardware requirements.

Software requirements:

- Operating system: Windows® 8 or later, Windows® 10 or later are anyway suggested (Windows® 11 included)
- Microsoft® .NET Framework 4.8 installed

Note for other operative systems (MacOS, UNIX …):

- XGSLab can works also on other operating systems using virtual machine with MS Windows® installed

Recommended Hardware requirements:

- CPU: Intel Core i5 for basic versions, Core i7, multi-core or more for higher versions

- Platform: 32- or 64-bit
- RAM: depending on module and maximum elements or cells number (see below)
- Hard Drive: 1 GB free space
- Monitor resolution: 1280x1024 pixels, 1920x1080 pixels (full HD) or more
- Port for protection key: USB 2.0 or USB 3.0
- OpenGL requires a Graphic Device that supports OpenGL 4.4 or upper (check your Graphics Card specifications for details)

The entire calculation process runs on the CPU and does not use any GPU features, so the graphics driver does not affect calculation performance. XGSLab uses parallel computing and some processes can be executed simultaneously, so multi-core CPUs can offer visible advantages in calculation performance, at least with a core number up to about 40.

Essentially, the calculation speed grows with the product “cores number * clock frequency”.
Some multi-core CPUs have a different clock frequency for cores, in such cases previous rule is not valid.

The vector graphic OpenGL is available only for 64 bit version.

For the *GSA* modules, the following RAM hardware requirements should be considered. As the maximum elements number is limited depending on the license profile, the following RAM requirements are suggested:
- Models with up to 2000 elements: at least 4 GB
- Models with up to 5000 elements: at least 4 GB for GSA and 12 GB for *_FD and XGSA_TD
- Models with up to 16000 elements: at least 20 GB for GSA and 64 GB for *_FD and XGSA_TD
- Models with more than 16000 elements: depending on the available RAM as in the figure below (note the log-log scale)

The following figure shows the RAM requirements as a function of the module and maximum elements number.

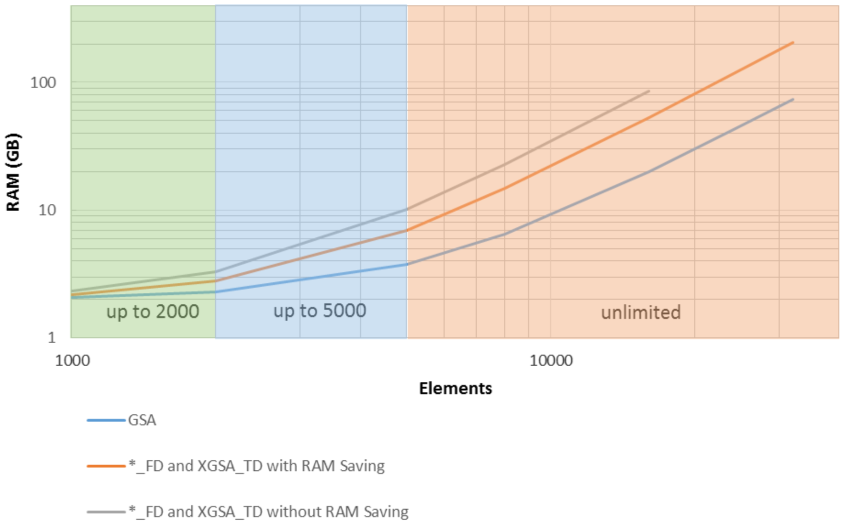

Figure 1-1: RAM requirements

1.5 DOES XGSLAB CAN WORKS ON WINDOWS 64 BIT?

In the past XGSLab was distributed both 32 bit and 64 bit.

Starting from version 10.1, XGSLab id distributed only as 64 bit.
The 64 bit version is fast in calculation and it can manages all available memory.

1.6 DOES XGSLAB REQUIRE A PROTECTION KEY?

The stand alone versions of XGSLab is protected with a hardware or software key.
The network versions of XGSLab is protected with a software key.

The hardware key is shipped via courier. Delivery time is usually in the range 1 – 4 working days.
The software key is sent via email. Delivery time is usually in the range 1 – 2 working days.
The program can be downloaded from our helpdesk web site. Accounts are usually sent in 1 – 2 working days.
All deadlines refer to the purchase order date.

1.7 DOES XGSLAB CAN BE USED IN REMOTE WAY?

We do not introduce limitations in using XGSLab in remote way using a VPN (Virtual Private Network) and Virtual Desktop but this use is possible only with a network key.
Stand alone key does not allows this use and in this case, the following error message appear.

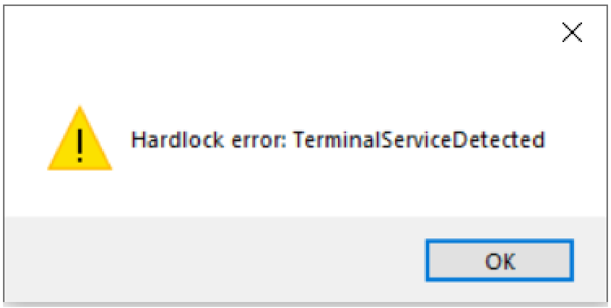

Figure 1-2: Error message in case of use of stand alone key in remote way

2. TECHNICAL

2.1 WHICH ARE THE STANDARDS USED BY XGSLAB?

XGSLab is based on physic laws and uses standard only in some specific circumstance, for instance.

Touch and Step Voltages limits:

- International standard: IEC/TS 60479-1:2005
- International standard: IEC/TS 60479-1:2018
- European standard: HD 637 S1:1999
- European standard: EN 50522:2010
- European standard: EN 50522:2022
- USA standard: IEEE Std 80-2000
- USA standard: IEEE Std 80-2013

Conductor Sizing:

- European standard: HD 637 S1:1999
- European standard: EN 50522:2010
- European standard: EN 50522:2022
- USA standard: IEEE Std 80-2000
- USA standard: IEEE Std 80-2013

Split Factor:

- European standard: HD 637 S1:1999
- European standard: EN 50522:2010
- European standard: EN 50522:2022
- USA standard: IEEE Std 80-2000
- USA standard: IEEE Std 80-2013

Lightning Shielding:

- International standard: IEC 62305-3:2010 (equal to EN 62305-3:2010)
- USA standard: IEEE Std 998-2012

Reference Standards considered by XGSLab are accepted in many countries in the World.

2.2 WHAT IS THE APPLICABLE FREQUENCY RANGE OF XGSLAB?

XGSLab can be applied in a frequency range from DC to about 100 MHz depending on the soil resistivity.

In any case, a limit of a few tens of MHz is conservative and should not be understood in an absolute sense.
This limit means that starting from a few tens of MHz, calculation accuracy gradually decreases.

The frequency range from DC to a few tens of MHz contains all power system frequencies, and the most significant frequency spectrum of the electromagnetic transient as represented in the following figure.
Corona effects are partially out of the application range.

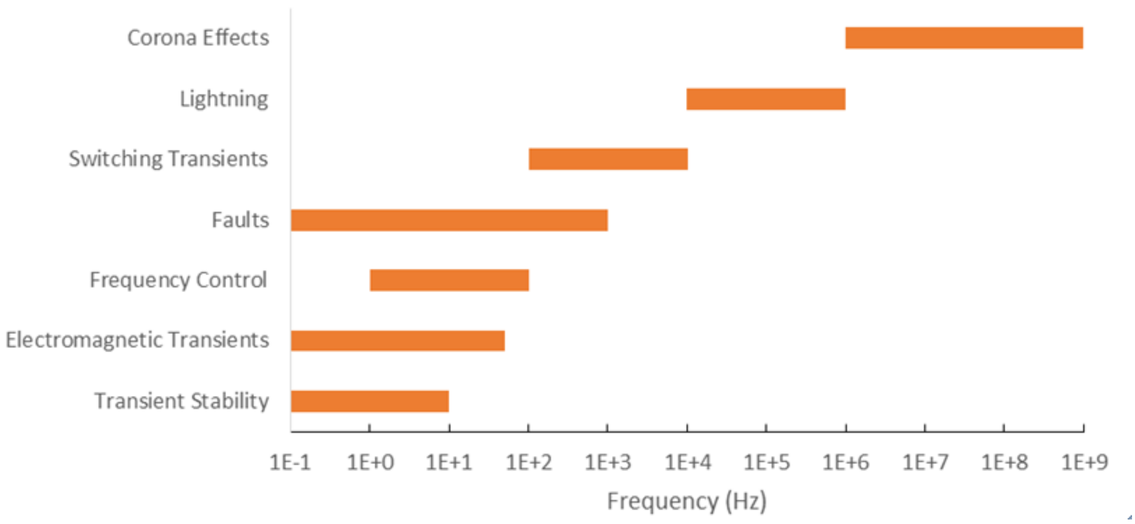

Figure 2-1: Frequency spectrum of electromagnetic phenomena

2.3 DOES XGSLAB CONSIDER MULTILAYER SOIL MODEL?

Yes, XGSLab considers the multilayer soil model.

The implemented algorithm is powerful and rigorous and can considers a multilayer soil model with an arbitrary layers number without constraints (for instance on layer thickness multiple of the thinner layer).

The choice of the soil model is crucial in electromagnetic simulations and in particular in the grounding systems analysis.

There is much literature about the criteria to set an appropriate soil model which can be used for predict the performances of a grounding system.

XGSLab allows to use uniform, multilayer and multizone soil models.

A uniform soil model should be used only when there is a moderate variation in apparent measured resistivity both in vertical and horizontal direction but, for the majority of the soils, this assumption is not valid.

A uniform soil model can also be used at high frequency because in that case, the skin effect limits the penetration depth of the electromagnetic field to a few meters and so, the soil resistivity of the depth layers do not affect the results.

The soil structure in general changes both in vertical and horizontal direction.

The vertical changings are usually predominant on the horizontal ones, but to correctly apply this concept it is essential to consider also the grounding system size.

In case of small grounding systems (maximum size up to a few hundred meters), soil model is not significantly affected by horizontal changings in soil resistivity and usually a multilayer soil model is appropriate. The layer number depends on the soil resistivity variations in vertical direction and three or four layers can be sufficient for most cases.

In case of grounding systems of intermediate size, soil model is affected by both horizontal and vertical changings in soil resistivity and usually an equivalent double or triple layer soil model is appropriate. This is the most important case in practical applications.

In case of large grounding systems (maximum size over a few kilometers), soil model is significantly affected by horizontal changings in soil resistivity and usually a multizone soil model is appropriate. The zone number depends on the systems size and soil resistivity variations in horizontal direction.

The use of a multilayer soil model with a great number of layers is important in case of evaluation of seasonal effects on soil model.

2.4 WHY THE DOUBLE LAYER SOIL MODEL IS ANYWAY IMPORTANT?

In case of grounding systems of large size, soil model is affected by both horizontal and vertical changings in soil resistivity and usually an equivalent double layer soil model is a good approximation.

The choice of an equivalent double layer soil model is often important for the following simple considerations that even a unskilled user can easily understand.

The soil resistivity is a parameter that is difficult to know with precision due to several variables:

- The resistivity of the upper layer changes with temperature, rain, pollution …
- The resistivity of the deep layers changes mainly with the kind of soil
- In case of large sites, horizontal resistivity variations is unavoidable
- In case of large sites, the soil surface often cannot be considered flat

In practical cases, a single soil model is not able to represent a large site, in all places and possible environmental conditions.

Therefore it is useless to refine soil models that inevitably are correct only in some specific point of the site.

A double layer soil model represents a good approximation because touch and step voltages depend mainly on the resistivity of the upper layer, where the electrode is usually buried, and the lower layers can be represented by one equivalent layer which mainly affects the equivalent resistance of the electrode.

In few words, in general, a double layer soil model is not a compromise but the only reasonable alternative to a uniform soil model.

In the following a true double layer soil model case.

The measurements at different sites indicate about the same model.

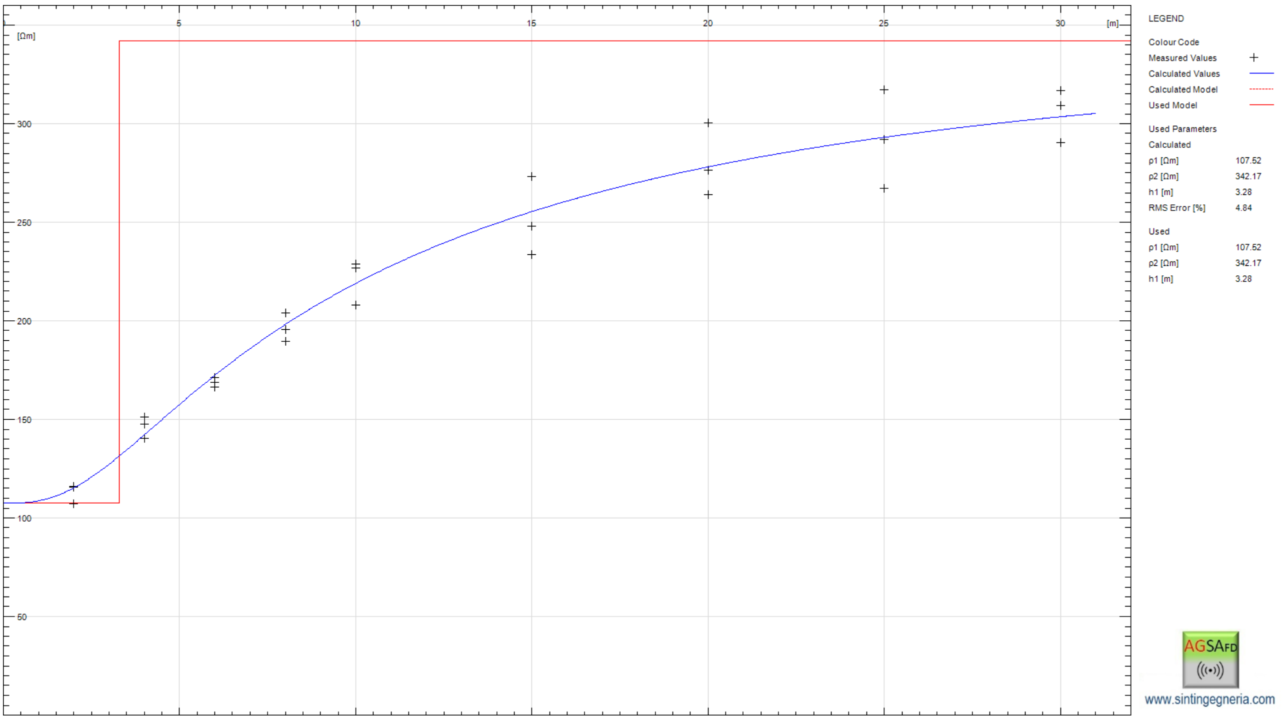

Figure 2-2: Soil resistivity measurements in case of true double layer soil model

In the following some false double layer soil model cases.

The measurements at different sites indicate different models.

XGSLab finds the general equivalent double layer soil model.

In these cases, a multilayer soil model with more than two layers usually does not improve the calculation.

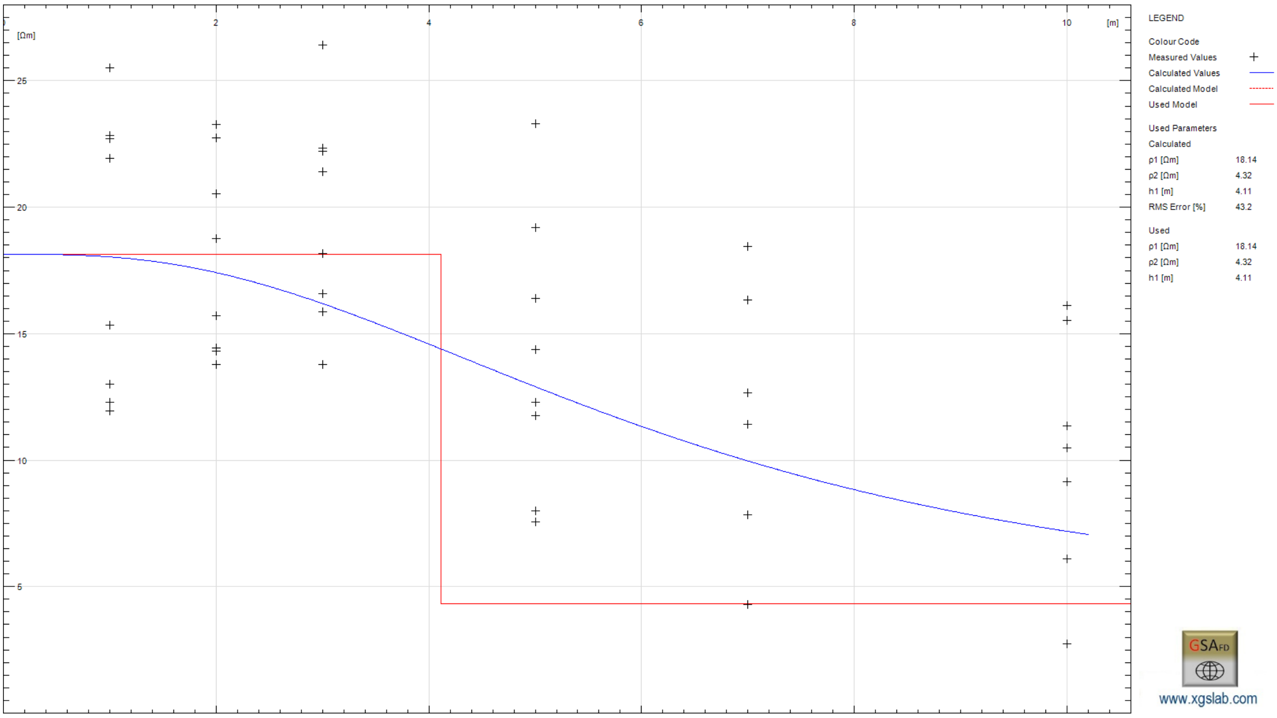

Figure 2-3: Soil resistivity measurements in case of false double layer soil model

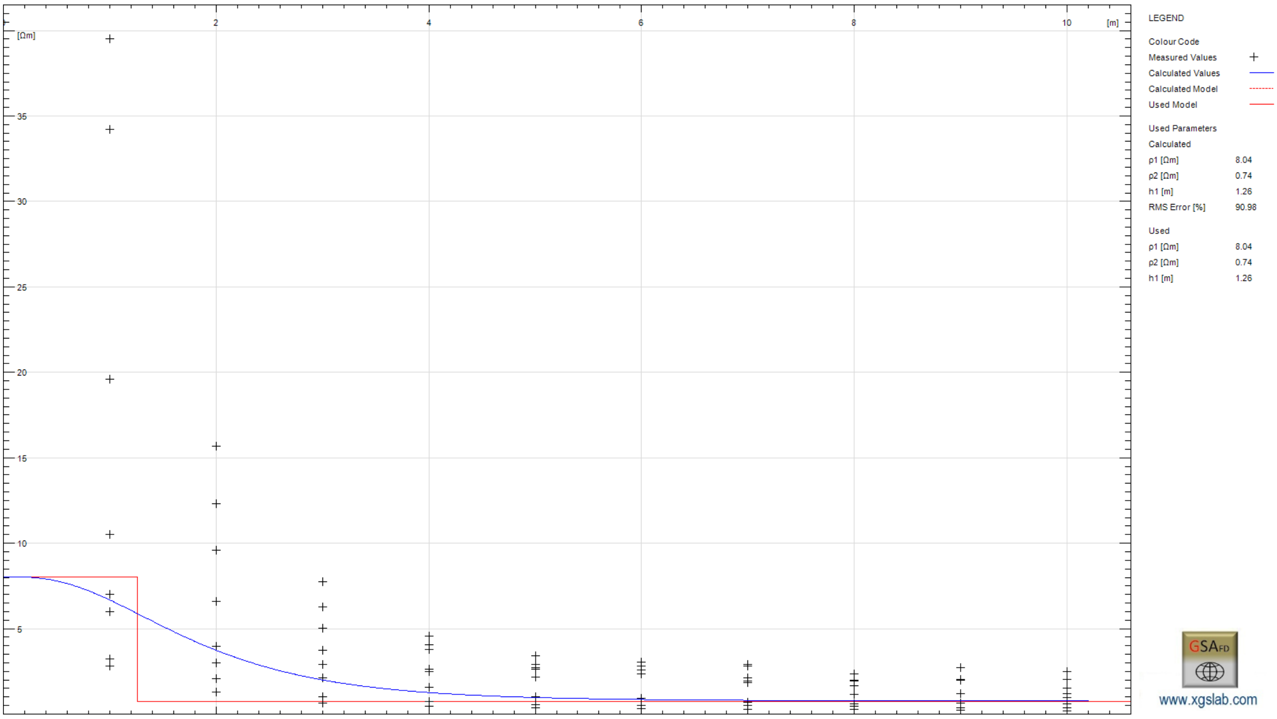

Figure 2-4: Soil resistivity measurements in case of false double layer soil model

2.5 WHEN IT IS IMPORTANT TO CONSIDER SOIL PARAMETERS FREQUENCY DEPENDENCE?

When frequency is over a few kHz soil resistivity and permittivity frequency dependence effects are not negligible.

When frequency grows, resistivity and permittivity change substantially and is fundamental to consider these effects in order to avoid large calculation errors.

There is not a general consensus about the soil parameter frequency dependence model.
XGSLab consider the following models:

- Messier
- Visacro – Portela
- Visacro – Alipio
- CIGRE TB 781 Model

In time domain calculation involving high frequency spectrum signals, if the soil parameters frequency dependence is neglected, calculation errors could be unacceptable.

2.6 WHY IT IS IMPORTANT A MODEL THAT CONSIDERS BOTH SELF AND MUTUAL IMPEDANCES?

Self impedances cannot be neglected in all systems where physical size is not negligible if compared to the wavelength length.
In practical cases and industrial frequency (50 or 60 Hz) self impedances cannot be neglected when the system size is over a few hundreds of meters.
In same conditions, mutual impedances cannot be neglected in case of large systems when soil resistivity is in the common range from 10 to 100 Ωm.
In general, neglecting self and mutual impedances can lead to very large errors.
Anyway, a parametric study showed that is not sufficient consider self impedances only.
The effect of mutual impedances can be significant and neglecting this parameter, the calculation error can be more than 25%.
In general, effects of self and mutual impedances grow with the grounding system size, with soil conductivity (inverse of resistivity) and with frequency.

2.7 IS IT POSSIBLE MODELING THE SOIL USING SOIL RESISTIVITY MEASUREMENTS?

Yes, it is possible to use both Wenner and Schlumberger resistivity measurements to obtain the soil parameters of uniform and multilayer soil models with an arbitrary layers number.
The on field measurements may be directly entered into the software including information about buried length of probes.
The algorithm to obtain soil parameters starting on resistivity measurements is based on the Trust Region Method and is very powerful and accurate and can manage constraints on results (results inside a given range).

2.8 WHAT THE MESSAGES "TOO SHORT ELEMENT" AND TOO LONG ELEMENT" MEAN?

XGSLab works with "thin" elements.
Thin mean that the length of the element must be much greater than its diameter.

In case of bare element, an element is thin if the length is at least 4 times the diameter for a warning message and 2 times for an error message.
In case of covered elements the rule is related to the external diameter out of covering.
Anyway elements cannot be too long.
The maximum length depends also on the system size and on the wavelength, then on soil resistivity and frequency.
The element length must be lower than “λ/10” for a warning message and “λ/6” for an error message.
The User Guide includes many details about that.
Anyway a correct fragmentation in elements is crucial for the calculation accuracy.

2.9 CAN I CONSIDER SOIL IONIZATION EFFECTS?

XGSLab does not consider directly soil ionization effects.
Soil ionization can appear only in case of small grounding systems (like a system for tower footing) and large currents to earth. In case of medium and large grounding systems (like a substation), this phenomenon can be neglected.
Anyway, it is possible to consider soil ionization effects by increasing the radius of conductors around which the electric field is over the critical value.
The user should perform a preliminary calculation without ionization, then calculate the new radius of conductors around which the electric field is over the critical value and run a second calculation.
The process is iterative but usually one or two iterations can be sufficient for an engineering purposes.
Normally, the ionization effect is quite moderate due to the dependence of the performance of earthing systems on the logarithm of the conductor radius.

2.10 CAN I CALCULATE AN INTERFERENCE WITH SYSTEMS AT DIFFERENT FREQUENCY?

GSA_FD and XGSA_FD can perform calculations using a single frequency at a time.
The possibility to export results in “csv” file can be useful in many cases.
For instance, in case of interference from independent systems with different frequency and the same victim (e.g the same pipeline), the total induced potential can be calculated using the effects superposition. As known, the effects superposition can be applied in linear systems, as usually happen in case of electromagnetic interference related to power lines.
This situation is quite common in Germany, where often, same tower lattices are used for power systems at 50 Hz and railways at 16.7 Hz.
In this case the calculation process can be the following:

- The User can perform a first calculation using the only systems at 50 Hz and then export the potential distribution along victims in numerical form in a “csv” file
- The User can perform a second calculation using the only systems at 16.7 Hz and then export potentials in numerical form in a csv file
- The total induced potential distribution along victims can be calculated using data in the “csv” files and the following equation (EN 50443:2012) for each element of victim

$$U = \sqrt{\sum_{i=1}^{n} |U_i|^2}$$

where:

- n = number of independent systems with different frequency
- U_i (V) = effective value of the induced potential from system i

2.11 CAN I CALCULATE AN INTERFERENCE BY PARTS AND THEN SUPERPOSE THE EFFECTS?

GSA_FD and XGSA_FD can perform calculations using a maximum number of elements depending also on RAM availability. In case of very large systems, when the maximum number of elements is not enough for a single model, the interference can be calculated by parts and then effects can be superposed.
The possibility to export results in “csv” file can be useful also in this cases.
In case of interference from independent systems with same frequency and the same victim (e.g the same pipeline), the total induced potential can be calculated using the effects superposition. As known, the effects superposition can be applied in linear systems, as usually happen in case of electromagnetic interference related to power lines.
In this case the calculation process can be the following:

- The User can perform a first calculation using the only sources part 1 and all victims and then export the potential distribution along victims in numerical form in a “csv” file
- The User can perform a second calculation using the only sources part 2 and all victims and then export the potential distribution along victims in numerical form in a “csv” file
- The total induced potential distribution along victims can be calculated using data in the “csv” files and the following equation (EN 50443:2012) for each element of victim

$$U = \sqrt{|U_1|^2 + |U_2|^2 + 2|U_1||U_2|\cos\gamma}$$

where:

- U_i (V) = effective value of the induced potential from system i
- γ (deg) = angle between induced potentials

In general the angle between induced potentials is unknown, and conservatively the formula to use is the following:

$$U = \sqrt{|U_1|^2 + |U_2|^2 + 2|U_1||U_2|} = |U_1| + |U_2|$$

Starting from release 10.2 the maximum number of elements has been increased from 16000+ to 32000+.
Then, previous approach by parts can be avoided, but it is anyway useful in case of limited RAM resources.

2.12 DOES XGSLAB CONSIDER THE END EFFECTS?

The modules based on field theory like GSA_FD, XGSA_FD and XGSA_TD are based on short conductors and consider mutual couplings and coefficient of potential using equations valid in the 3D space. Then they consider end effects.
The module NETS is based on circuit theory and consider equations based on the assumption of infinite length conductors, as usual in similar tools like EMTP. Then it does not consider end effects.
The end effects are evident when the assumption of infinite length conductors is not valid, then they depend on length and mutual distance between conductors.

The difference between results with and without taking into account end effects can be relevant (even an order of magnitude and beyond).
This effect is sometimes overlooked and not known to many engineers.
As general rules, equations based on the assumption of infinite length conductors are valid only in case of parallel conductors with a ratio between length and distance more than 50 for an excellent agreement and 20 for a good agreement.

2.13 ON WHICH CALCULATION METHOD XGSLAB IS BASED?

The modules GSA, GSA_FD, XGSA_FD and XGSA_TD are based on electromagnetic field theory (Maxwell equations, Sommerfeld integrals and Jefimenko equations), on mathematical transformations (Fourier transforms) and the numerical method PEEC (Partial Element Equivalent Circuit) in full-wave conditions.

The PEEC is a BEM (Boundary Element Method) developed in about 1990, and allows to simulate systems of conductors integrated with circuit components like generators and impedances.
Many people do not know the difference between BEM and FEM (Finite Element Method) but the difference is crucial.
Essentially with FEM the discretization is applied to the propagation medium, with BEM the discretization is applied to the sources.
FEM is a numerical method for solution of partial differential equations and is really useful in some applications, but hard to use for engineering purposes because the modelling difficulties in case of unbounded scenarios and the hardware requirements.
BEM is numerical method in integral form perfectly suitable for engineering purposes.
All main software in the market like CDDEGS®, WinIGS®, CYME®, ETAP®, ELEK® are based on BEM.

The module NETS is based on circuit theory (graphs theory and Kirchhoff laws), on power lines, cables and transformers theory and the numerical method PCM (Phase Components Method).
Many people knows the method SCM (Sequence Component Method) but do not know PCM.
In particular many people do not know the application limits of the SCM.
We used the PCM because this method is for general purposes and can be applied with multiphase and multiconductor systems, symmetrical or not, balanced or not and in particular can consider multiple grounded systems and problems that involve currents to earth.
In general, the SCM cannot be used in case of multiple grounded systems.
WHY SOMETIME POTENTIAL CALCULATED CLOSE TO ELEMENTS IS NOT AS EXPECTED?
The modules GSA, GSA_FD, XGSA_FD and XGSA_TD are based on the PEEC numerical method.
The system of conductor is divided in short elements.
With a first calculation step, the program determines charges, currents and potentials on each element.
With a second calculation step, the program determines potentials and fields in the propagation medium as superposition effects of all elements.
The calculation of potentials assumes a uniform charge distribution (or leakage current distribution) along each element.
As a consequence, the potential close to the elements will not be uniform and then will be in general different from the actual element potential.
The potential distribution related to a uniform charge distribution in a single element can be represented using ellipsoids in the 3D space.
Far away from the elements these ellipsoids becomes spheres and calculation is as expected. But close to the elements potential distribution differ from ellipsoids and there are no analytical equations to express them.

XGSLab use algorithms that gradually correct the potentials very close to the elements by forcing their value to the known one.
These algorithms work well very close to the elements, while far to the elements no correction is necessary.
There is a transition zone where algorithms do not work.
In this intermediate zone potential could be not as expected, in some condition also more than the potential of the closest element.
The problem is limited to some specific conditions and close to the elements.

2.14 IS IT POSSIBLE IMPEDANCE TO EARTH INCREASES WHEN SYSTEM SIZE INCREASES?

Yes, this is unexpected but possible when the system size is comparable or bigger than the electromagnetic wavelength in the propagation medium.
At low frequency, when soil permittivity effects are negligible if compared to resistivity effects, the electromagnetic wavelength can be calculated using the following formula:

$$\lambda = 3162\sqrt{\frac{\rho}{f}}$$

where:
- λ (m) = wavelength
- ρ (Ωm) = soil resistivity
- f (Hz) = frequency

For instance:
- If f = 100 kHz and ρ = 100 Ωm, λ = 100 m
- If f = 10 kHz and ρ = 100 Ωm, λ = 316.2 m
- If f = 1 kHz and ρ = 100 Ωm, λ = 1000 m
- If f = 100 Hz and ρ = 100 Ωm, λ = 3162 m

Considering a simple system with a single wire and injection point located at an end, the behaviour is the following:
- The impedance decrease when length increase and length is much shorter than wavelength
- The impedance increases when length increase and length is comparable to wavelength
- For even greater lengths the behaviour is oscillating but damped by the dissipative medium

2.15 IS IT POSSIBLE TO REPRESENT CONCRETE ENCASED CONDUCTORS?

Yes, this is possible, but it is important to consider different opinions in literature.

You could avoid to represent the concrete. The buried concrete is hygroscopic and tends to attracts moisture and salts from surrounding soil, and with time (years) the concrete resistivity becomes similar to the soil resistivity.

The other option is to consider the concrete as a cylindrical shell around buried conductors. The shell thickness is usually in the range 3 - 5 cm and represents the minimum concrete thickness between conductors and soil.

The problem is how to fix the concrete resistivity value. IEEE Std 80-2013 states that the common value of concrete resistivity is in the range 30 – 200 Ωm, so a quite wide range. If you consider an average value of concrete resistivity 100 Ωm, you can understand that concrete give advantages in resistance to earth only if the surrounding soil resistivity is less than 100 Ωm, so quite low.

You can easily add a concrete shell to conductors as in the following.
You can create a new conductor and set the coating parameters using concrete.

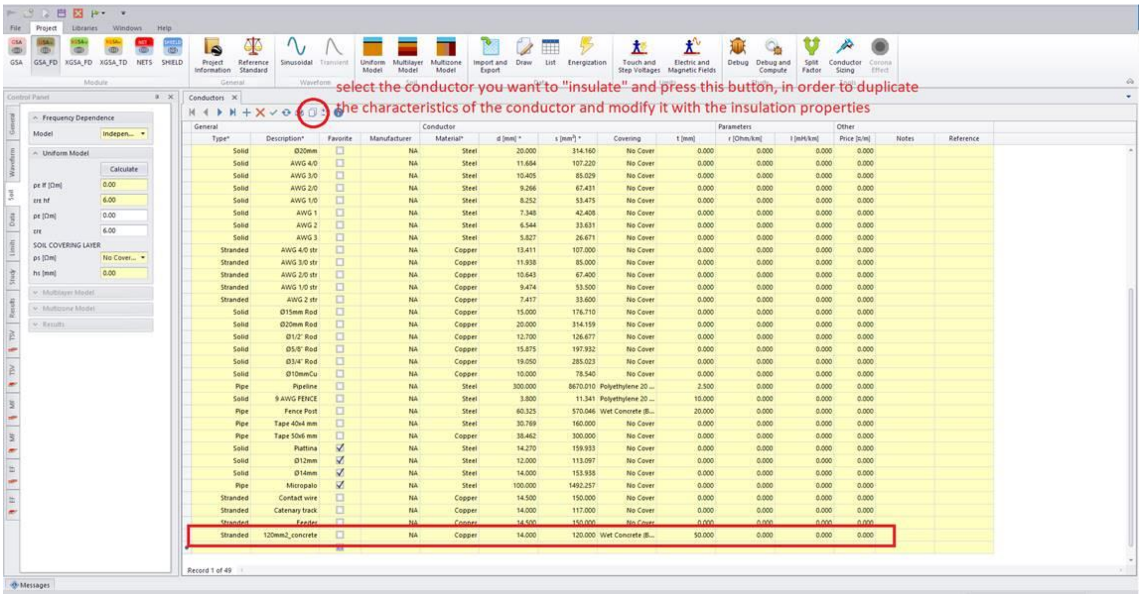

Figure 2-5: Conductor properties

After that, you can set the conductor you want to consider as concrete encased with the specific created new conductor.

2.16 CAN I CONSIDER ADDITIONAL RESISTANCES IN IEEE STANDARDS LIMITS?

As known, IEEE 80 Standard does not consider hand and foot contact additional resistances, and this is a conservative assumption. This is the reason why, with IEEE 80 Standard and old XGSLab releases, the User could not set the additional parameters “Rsh” and “Rgl”.

In new XGSLab releases, this constraint has been removed. This because the IEEE 2778 Standard “IEEE Guide for Solar Power Plant Grounding for Personnel Protection” allows to consider additional shoe and glove resistance. These additional resistances can be easily taken into account by setting “Rsh (Ω)” (resistance of a single shoe) and “Rgl (Ω)” (resistance of a single glove) in the panel for the calculation of Touch and Step Voltages Limits (see figure below).

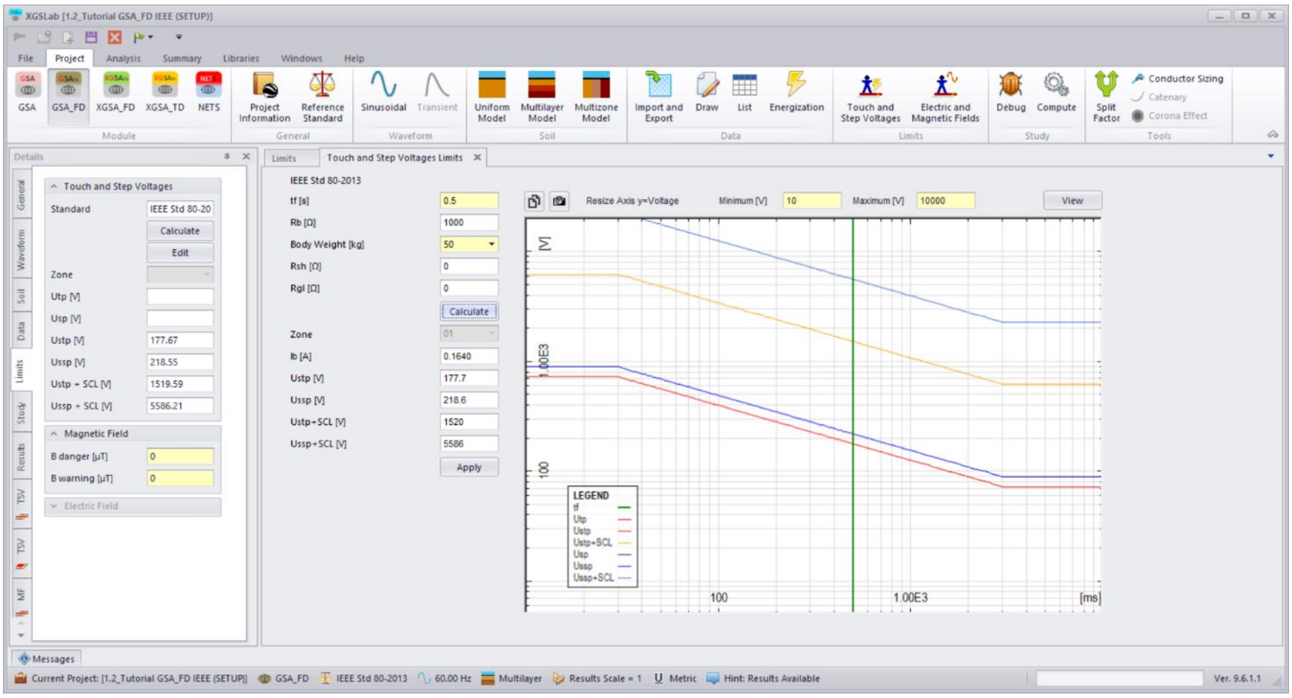

Figure 2-6: Touch and Step Voltages Limits

The prospective permissible touch and step voltages with additional resistances (below indicated with a symbol +) without and with soil covering layer (SCL) are calculated by using the following equations:

$$U_{STP+} = \left(R_B + R_f/2 + R_{shoe}/2 + R_{glove}\right) I_B$$

$$U_{SSP+} = \left(R_B + 2R_f + 2R_{shoe}\right) I_B$$

$$R_f = \frac{\rho_e}{4b} = \frac{\rho_e}{4 \cdot 0.08} = 3.125\rho_e \quad \text{without SCL}$$

$$R_f = \frac{C_s\rho_s}{4b} = \frac{C_s\rho_s}{4 \cdot 0.08} = 3.125 C_s\rho_s \quad \text{with SCL}$$

where:

- R_B (Ω) = body resistance
- R_f (Ω) = ground resistance of one foot
- R_{shoe} (Ω) = additional resistance of a shoe
- R_{glove} (Ω) = additional resistance of an insulating glove
- I_B (A) = tolerable body current
- ρ_e (Ωm) = ρ_e or ρ_1 for uniform or multilayer soil model respectively
- ρ_S (Ωm) = soil covering layer resistivity
- C_S = reduction factor related to the soil covering layer
- b (m) = equivalent radius (0.08 m)

The relation between permissible touch and step voltages with and without additional resistances is the following:

$$U_{STP+} = U_{STP} + \left(R_{shoe}/2 + R_{glove}\right) I_B$$

$$U_{SSP+} = U_{SSP} + 2R_{shoe} I_B$$

For instance, if t_f = 0.5 s and Body Weight = 50 kg, I_B = 0.164 A, U_{STP} = 189.7 V and U_{SSP} = 266.6 V.
If the resistance of a single shoe is 2000 Ω and no gloves are considered, the new permissible touch and step voltages will be respectively:

U_{STP+} = 189.7 + (2000/2)*0.164 = 353.7 V

U_{SSP+} = 266.6 + 2*2000*0.164 = 922.6 V

2.17 CAN I USE LIBRARIES IN MY COMPUTER IN OTHER COMPUTERS?

The simplest way to do that is to open a project (let us call it “NewItemsPrj”) that has those new items you are interested in, in the computer (let us call it “2ndPc”) in which you want to carry the new items.
Once you have opened NewItemsPrj in 2ndPc you have to go to this section:

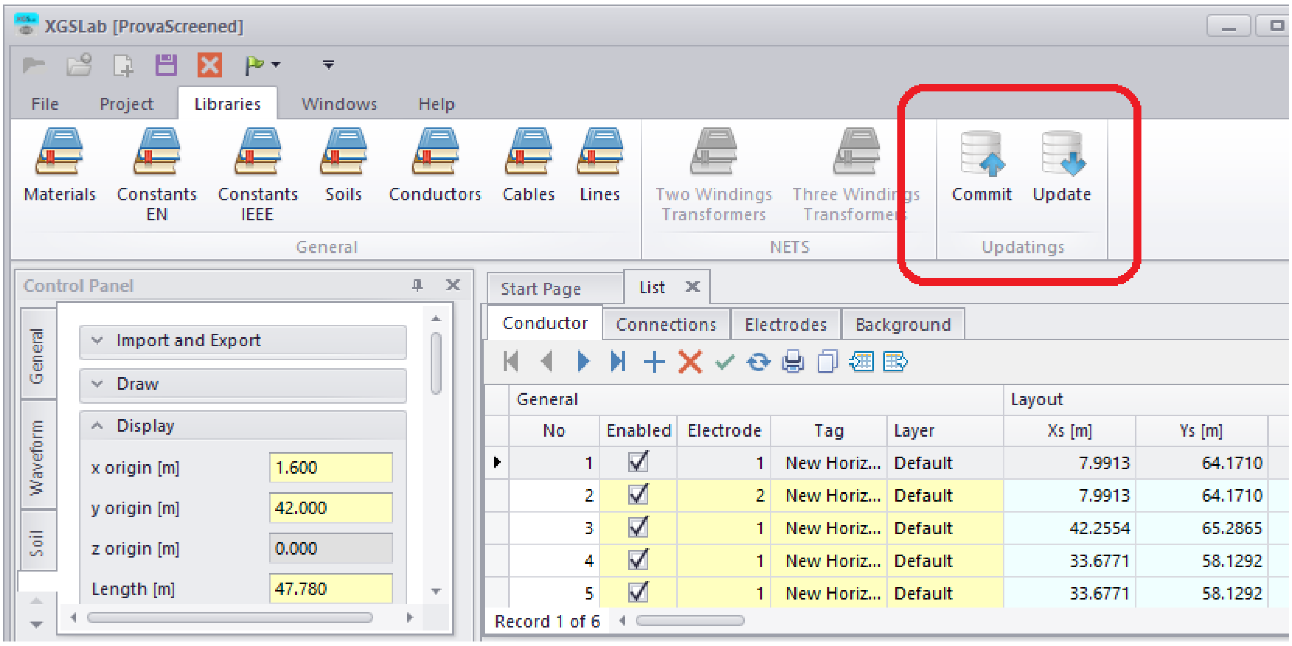

Figure 2-7: Commit and Update menu options

If you click on “Commit” you make the new items present in the data base of NewItemsPrj available also for all the future projects that will be created in 2nd Pc.

Moreover, once executed the “Commit”, if you want to have the new items also in a project (let us call it “OldPrj2ndPc”) created before the commit, you have to open OldPrj2ndPc and click “Update” in the section of the main tool bar circled in the picture here above.

Pay attention to these constraints:

- The same description cannot be used twice
- The same properties can be set for different description

These conditions have been introduced recently and they face databases built with old and more "relaxed" constraints. This implies that it is very likely you will find a message like this.

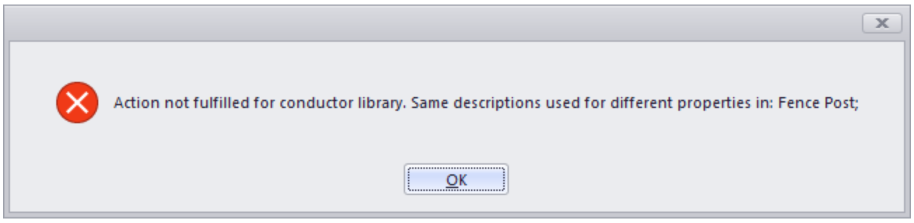

Figure 2-8: Error message

In case this message pops up there are two alternative ways to overcome it:

- Rename the record(s) pointed out (in the picture here above "fence post" in the "conductor library")
- Delete the record(s) pointed out

Finally consider also that, at the moment, when you update the software, the database of libraries is again the initial one. To make it contain all the customizations you did in the past you have to open a project created before the updating of the software and execute a commit from there.

2.18 WHAT IS THE MAXIMUM NUMBER OF LAYERS IT IS POSSIBLE TO CALCULATE?

Usually soil resistivity measurements are based on Wenner and Schlumberger methods.
The apparent soil resistivity can be calculated from measurement using the following equation:

$$\rho_m = \frac{2\pi R}{\frac{1}{c} - \frac{1}{a+c} + \frac{1}{\sqrt{c^2 + 4b^2}} - \frac{1}{\sqrt{(a+c)^2 + 4b^2}}}$$

where:

- R (Ω) = Wenner or Schlumberger resistance
- a (m) = spacing between voltages probes
- b (m) = probes depth
- c (m) = spacing between voltages and current probes (in case of Wenner method c = a)

The apparent soil resistivity can be calculated also starting from the soil model parameters.
For instance, for a multilayer soil model it is possible to calculate:

$$\rho_c = \rho_c\left(a, c, \rho_1, \rho_2, \cdots \rho_n, h_1, h_2, \cdots h_{n-1}\right)$$

where:
- a (m) = spacing between voltages probes
- c (m) = spacing between voltages and current probes
- ρ_i (Ωm) = resistivity of layer i
- h_i (m) = thickness of layer i

The calculation of layer parameters (resistivity and thickness) can be done using a minimization algorithm which lead to the minimum of the following squared error function:

$$\psi\left(\rho_1, \rho_2, \cdots \rho_n, h_1, h_2, \cdots h_{n-1}\right) = \sum_{i=1}^{N}\left[\frac{\rho_m\left(a_i, c_i\right) - \rho_c\left(a_i, c_i, \rho_1, \rho_2, \cdots \rho_n, h_1, h_2, \cdots h_{n-1}\right)}{\rho_m\left(a_i, c_i\right)}\right]^2$$

where:
- a (m) = spacing between voltages probes
- c (m) = spacing between voltages and current probes
- ρi (Ωm) = resistivity of layer i
- hi (m) = thickness of layer i
- N = number of measured resistivity values

Previous equation can include weight functions, but this is not essential for the following considerations.
The number of unknowns in previous minimization problem is P, a resistivity and a thickness for each layer except the bottom layer with infinite depth. It follows:

$$P = 2L - 1$$

where:
- L = number of layers

As known, in case of a linear system, the number of independent equation must be the same of the unknown.
In the specific case, the minimization algorithm can find also more unknowns than equations, but in XGSLab the following conservative checks has been implemented:
- If the number of independent measurements N is lower than 2P, the following message is shown “Warning: poor number of measurements with different electrode spacings”. In this case the calculation is done
- If the number of independent measurements N is lower than P, the following message is shown “Error: insufficient number of measurements with different electrode spacings”. In this case the calculation is not done

Independent measurements means Wenner and Schlumberger measurements with different electrode spacings.
For instance, if L = 5, P = 9 and then, the minimum number of independent measurements is 9, the minimum suggested number of independent measurements is 18.

3. DEMO

3.1 BETTER A DEMO OR A WEB BASED PRESENTATION?

According to our experience a web based presentation can be more effective than a demo in showing XGSLab features in a short time.

It is possible to ask for a web presentation to our Customer Service at sales@xgslab.com.

By the way, you can require also a demo application to us.

Demo version is available as online and keyless license, It is limited in time and features but can be useful to try XGSLab.

3.2 HOW TO ACTIVATE CAMEYO ONLINE DEMO?

When your demo request has been processed, you receive the email below:

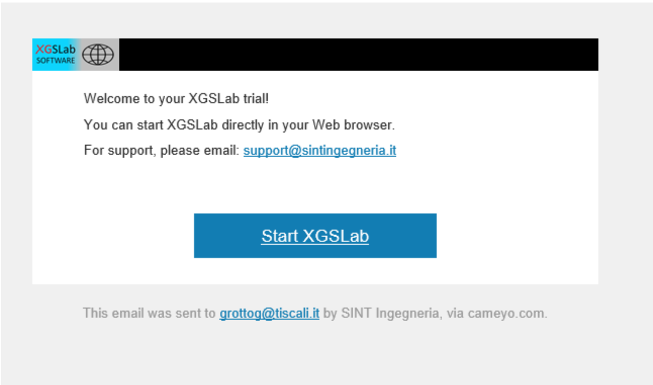

Figure 3-1: Welcome mail with link

Click on “Start XGSLab” in order to test XGSLab on web browser.

Wait a few seconds until program is loaded.

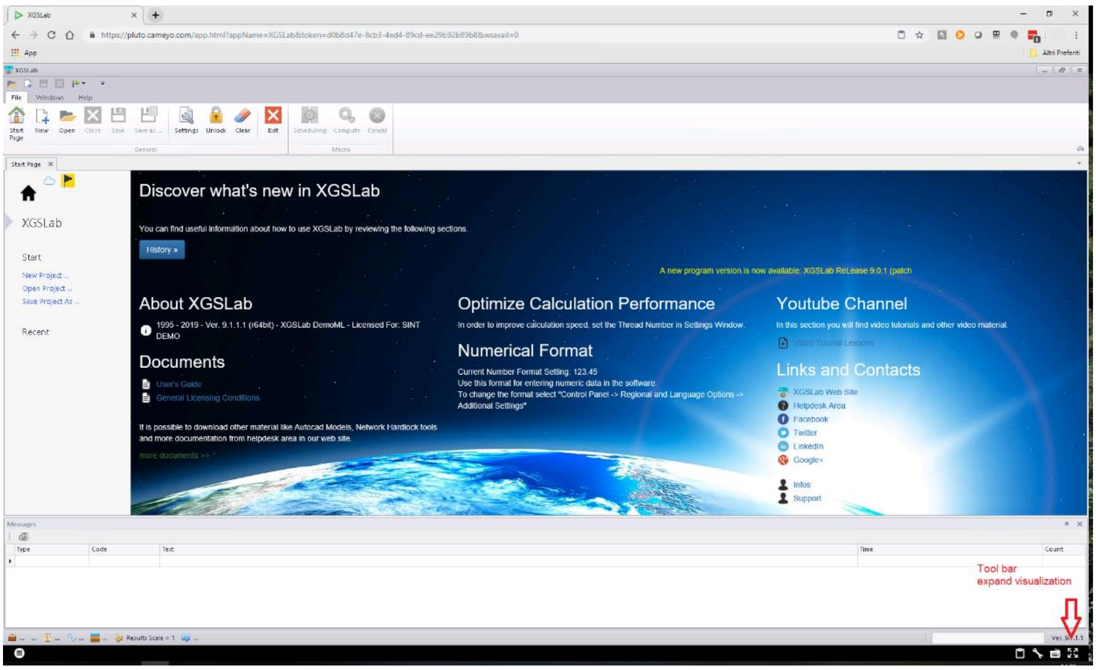

Figure 3-2: XGSLab on Browser

The demo version can use existing tutorial projects.
These projects can be opened, used and saved in your PC.
Tutorial Projects are located on: Documents\XGSLab\Projects
In order to save a file use function “Download” on Desktop area.
In order to load a file “Upload” it from Desktop.
There is no persistence, meaning whatever the user does to the projects in one session does not follow to the next session.
The original projects cannot be modified by users.
When a user section terminates all data on server will be removed, so download your project before closing.

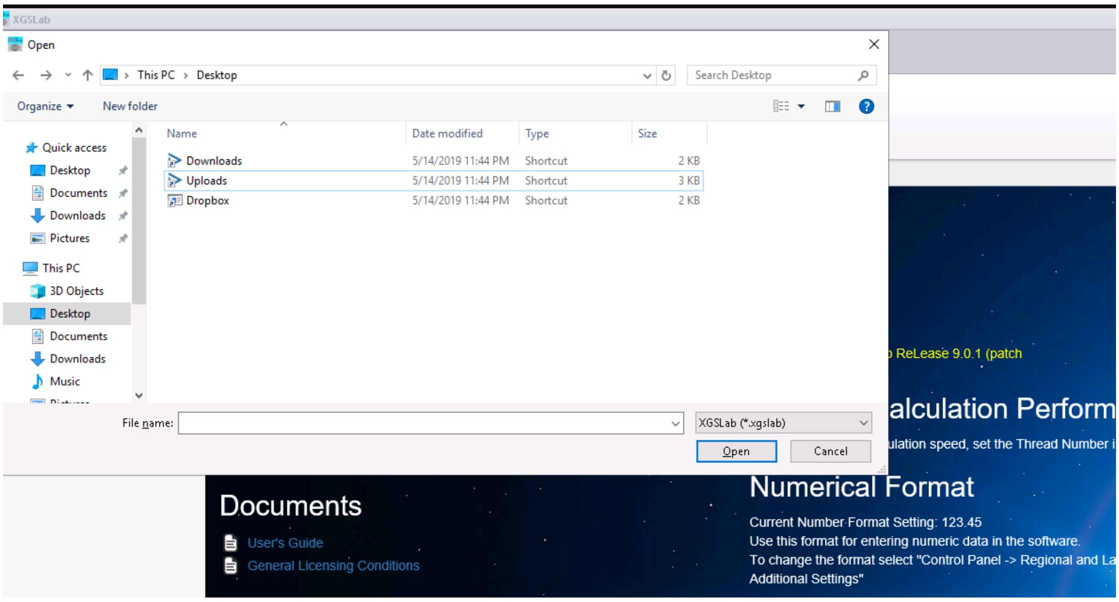

Figure 3-3: Desktop for saving new test projects

3.3 HOW TO IMPORT EXTERNAL FILES IN THE CAMEYO ONLINE DEMO?

The demo version can load external dxf files.
Shortly, you can follow the following steps:
1) Create a Project
2) Click on menu “Import and Export”
3) Set a “dxf” file in the “Path” box (click on folder icon)
4) Drag the file in the select “Drag and Drop” folder and confirm …

In order to import external file in the application (eg. dxf) or export file project use these instructions:

You can click \\tsclient\Storage, which is pinned to Quick access, and will be taken directly to where uploaded files are.

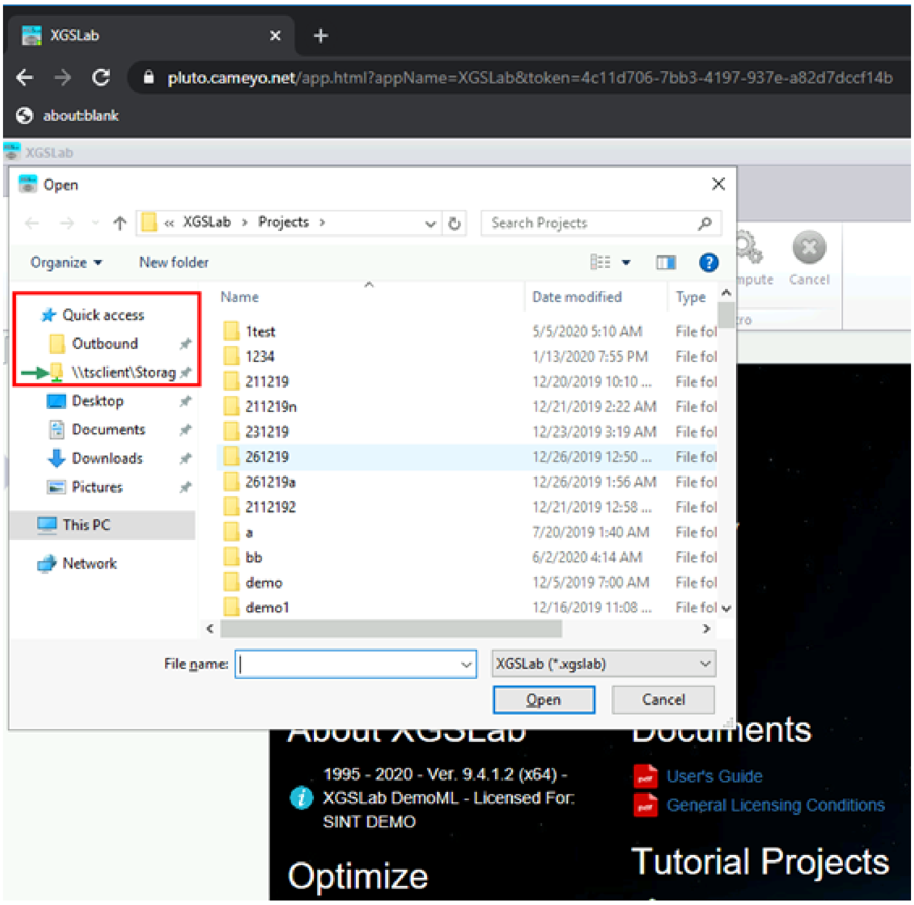

Figure 3-4: Import of external files – Step 1

Then you have to select “All files (“.”) as file type to be able to see

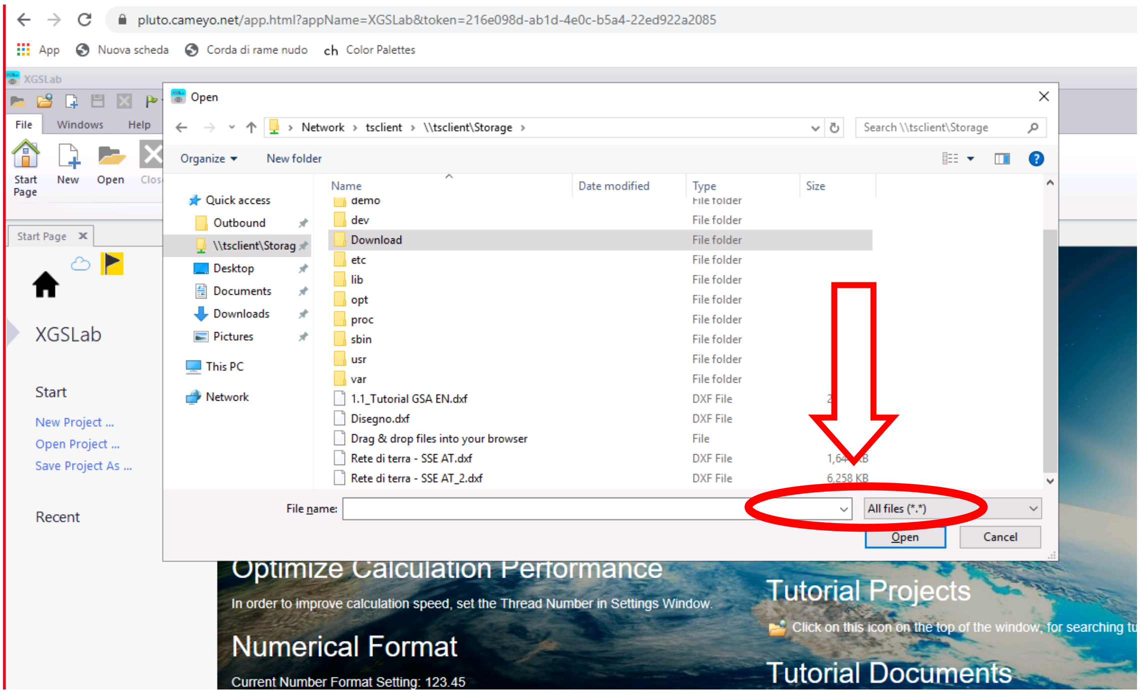

Figure 3-5: Import of external files – Step 2

Now you have to drag and drop in the \\tsclient\Storage folder the file you are interested in

Finally, you can right click in the files area and click Refresh instead in order to be able to view the dragged file.

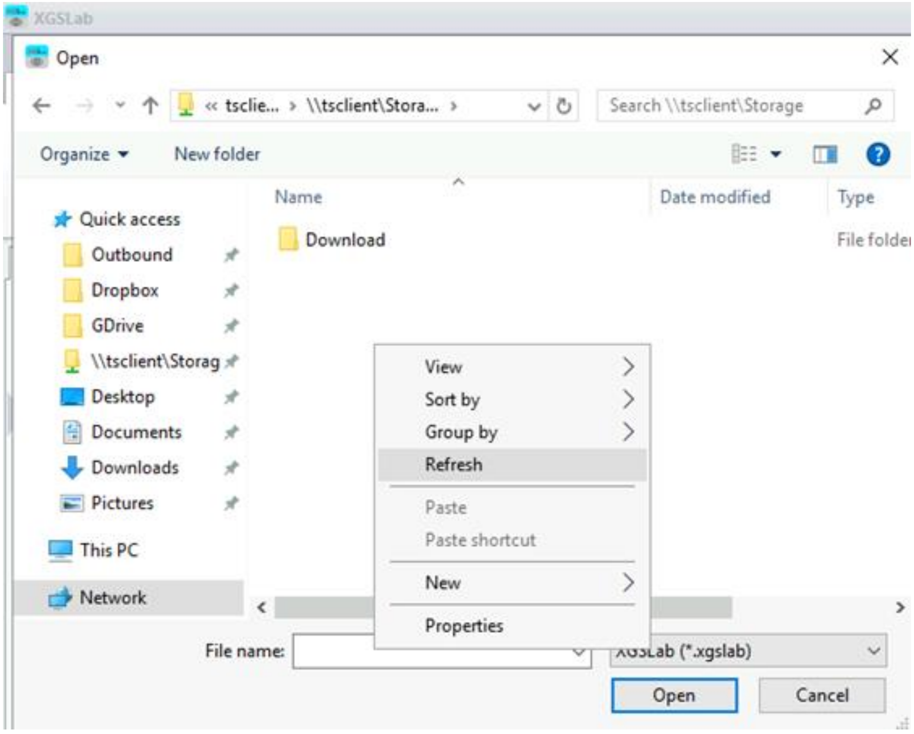

Figure 3-6: Import of external files – Step 3