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XGSLab™

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

GENERAL BROCHURE [September 2018]

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EASY

Integrated and modular program with a modern and intuitive interface and a high quality graphics. Easy even for beginners.

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ELECTROMAGNETIC SIMULATION FOR POWER, GROUNDING AND LIGHTNING PROTECTION SYSTEMS

XGSLab is one of the most powerful software of electromagnetic simulation for power, grounding and lightning protection systems and the only software on the market that takes into account IEC, EN and IEEE Standards in grounding system analysis.
XGSLab includes the modules:

- GSA (GROUNDING SYSTEM ANALYSIS) for basic application with underground systems
- GSA_FD (GROUNDING SYSTEM ANALYSIS in the FREQUENCY DOMAIN) for general applications with underground systems
- XGSA_FD (OVER AND UNDERGROUND SYSTEM ANALYSIS in the FREQUENCY DOMAIN) for general applications with overhead and underground systems
- XGSA_TD (OVER AND UNDERGROUND SYSTEM ANALYSIS in the TIME DOMAIN) for general applications with overhead and underground systems
- NETS (NETWORK SOLVER) solver for multi-conductor and multi-phase full meshed networks

GSA, GSA_FD, XGSA_FD and XGSA_TD integrate the module SRA (SOIL RESISTIVITY ANALYSIS) and XGSA_TD integrates also the module FA (FOURIER ANALISYS direct / inverse).
NETS integrates the routine for the calculation of lines, cables and transformers parameters.
The XGSLab application field is so wide because the implemented model is for general use and solves the Maxwell equations in non stationary conditions taking into account the earth lack of homogeneity by the Green functions, the earth reaction by the Sommerfeld integrals and moving from the frequency to the time domain by means the Fourier transforms.
All modules are integrated in an “all in one” package and based on a hybrid calculation method (or “PEEC” method) which considers transmission line, circuit and electromagnetic theory combined into a single calculation model. Hybrid methods join the strong points of the other methods and are well suited for engineering purposes because they allow the analysis of complex scenarios including external parameters such as voltages, currents and impedances. For these reasons, XGSLab can be considered a real laboratory.
All algorithms implemented in XGSLab are highly efficient in terms of computation speed and has been validated and tested by many Customers in the world.
XGSLab is easy to use by engineers who need not to be necessarily experts in the specific field, and moreover accurate, stable and fast.
Everything possible has been done to enhance user friendliness and increase productivity to this powerful tool.

GROUNDING SYSTEM ANALYSIS

GSA is a widely utilized and recognized module for earth grid calculations and design including soil resistivity analysis.
GSA is based on the equipotential condition of the electrodes and can analyse the low frequency performance of grounding systems composed by many distinct electrodes of any shape into a uniform or multilayer soil model.
GSA can import earth grid data from “dxf” files, delivering professional numerical and graphical output useful for investigation of GPR and leakage current, earth potential, touch and step voltage distributions.
GSA can also export data and results in “dxf” files and this allows a full interactivity with CAD tools.

GROUNDING SYSTEM ANALYSIS in the FREQUENCY DOMAIN

GSA_FD is a module for earth grid calculation and design in the frequency domain, including soil resistivity analysis and represents the state of the art of grounding software.
GSA_FD is also useful for magnetic field and electromagnetic interference evaluations.
GSA_FD adopts a rigorous approach to the study of very large grounding systems where experience shows that the horizontal variations of the soil resistivity makes inefficient sophisticated soil models (multilayer). In these cases, an accurate electric model of the electrodes including self and mutual impedances is fundamental. These parameters can be known with greater certainty than the soil resistivity because in the frequency range we are interested in, these parameters depend weakly on the soil properties.
Moreover, taking into account self and mutual impedance effects, allows to overcome the equipotential condition of the electrodes on which standard GSA is based.
This allows the analysis of electrodes whose size are comparable with the wavelength as better specified in the following.
A few competitors take into account self impedance and a very few competitors consider the mutual impedance effects and this can lead to significant errors in calculations.
With the equipotential condition hypothesis, the maximum touch voltage is widely underestimated and this may result in grounding system oversizing with additional cost sink even 50%.
Neglecting the mutual impedances can lead to errors over the 20% in calculations. GSA_FD can allow a significant cost saving in grounding system construction and materials.
GSA_FD can be used in the frequency domain range from DC to 10 MHz and then the calculation accuracy gradually decreases but results are often reliable over 10 MHz and positive tests have been made up to 50 MHz.
GSA_FD takes into account the frequency dependence of soil parameters and allows setting the used model.
GSA_FD can analyse grounding systems composed by many distinct electrodes of any shape, size and kind of conductor (solid, hollow or stranded and coated or bare) into a uniform, multilayer or multizone soil model.
Similarly to GSA, GSA_FD can also import earth grid data from “dxf” files delivering professional numerical and graphical output useful for investigation of GPR and potential, current, leakage current, earth potential, touch and step voltage distributions.
As GSA, GSA_FD can also export data and results in “dxf” files.
In DC conditions GSA_FD is a good tool for cathodic protection and anode bed analysis with impressed current systems.
GSA_FD can also calculate magnetic fields due to grounding systems or cable, and electromagnetic interference (induced current and potential due to resistive, capacitive and inductive coupling) between grounding systems or cable and pipeline or buried electrodes in general.

OVER AND UNDERGROUND SYSTEM ANALYSIS in the FREQUENCY DOMAIN

XGSA_FD extends the GSA_FD application field to the overhead systems.
XGSA_FD can also manage catenary conductors and bundle conductors too and can take into account sources where potential or leakage current and longitudinal current are known and independent by other conditions. For these reasons XGSA_FD is probably one of the most powerful and multipurpose tools on the market for these kind of calculations.
In addition to GSA_FD, XGSA_FD can calculate electromagnetic fields and interference between over and under ground systems (for instance between overhead or underground power lines and installation as pipelines, railways or communications lines) and also the fault current distribution.
Electric and magnetic fields are calculated by means the Jefimenko’s equations and then taking into account the propagation effects.
XGSA_FD calculation model is directly derived from GSA_FD and its application limits can be considered the same.

XGSA TD

OVER AND UNDERGROUND SYSTEM ANALYSIS in the TIME DOMAIN

XGSA_TD is a powerful module which extends the XGSA_FD application field to the time domain.
In this regard, XGSA_FD uses the so called "frequency domain approach". This approach is rigorous and allows considering the frequency dependence of soil parameters.
As known, a transient can be considered as the superposition of many single frequency waveform calculated with the forward Fourier transforms.
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.

NETS

NETWORK SOLVER

NETS is a very flexible tool to solve full meshed multi-conductor and multi-phase networks and is based on the multi-phase system representation.
This approach is general and overcome the classic method of symmetrical components and can be used to represents power systems as multi-conductor networks enabling the consideration of asymmetrical and/or unbalanced systems also in presence of grounding circuits or circuits with a different phases number.
The network components (generators, lines, cables, transformers, loads, switches, faults ..) are represented with multi-port cells and the connection between cells is obtained by means of multi-port buses.
NETS calculates lines, cables and transformers parameters starting on data normally available in commercial data sheet.
Like the other XGSLab modules, also NETS has been thought for a use as general as possible.
NETS can be used to solve transmission and distribution networks in steady state or fault conditions and to calculate potentials and currents or short circuit currents (three phase, phase to phase, phase to phase to earth, single phase to earth) with or without fault impedances.
In particular, NETS can be used for the calculation of the fault current distribution in power networks.
Another typical application of NETS is related to the neutral grounding resistor sizing.
NETS is then a very useful tool to calculate data input for others XGSLab modules (for instance the split factor or the current to earth) and represents the link between XGSLab and the most diffused commercial software for power systems analysis.

PRODUCT FEATURES AND POSSIBLE APPLICATIONS

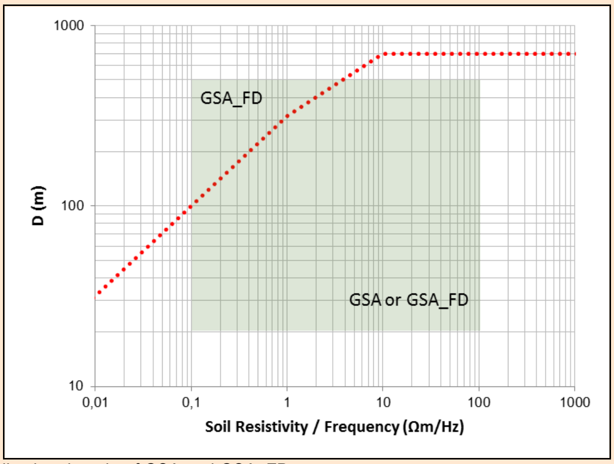
PRODUCT FEATURES	GSA	GSA_FD	XGSA_FD	XGSA_TD	NETS
Electromagnetic Fields Theory Based	✓	✓	✓	✓	
Multi-conductor and Multi-phase Circuits Theory Based					✓
IEC, EN and IEEE Standards	✓	✓	✓		
Soil Resistivity Analyzer suitable for both Wenner and Schlumberger measures	✓	✓	✓	✓	
Uniform Soil Model	✓	✓	✓	✓	
Double Layer Soil Model	✓	✓	✓	✓	
Multilayer Soil Model with an arbitrary layers number (* ML and research version)	✓	✓	✓	✓	
Multizone Soil Model		✓	✓		
Up to 99 Distinct Electrodes	✓	✓	✓	✓	
Layout Graphical Input from “dxf” and Export to “dxf” files	✓	✓	✓	✓	
Integrated Drawing Tool	✓	✓	✓	✓	✓
Automatic Nodes (or Buses) Recognition		✓	✓	✓	✓
Automatic Span Division and Conditioning		✓	✓	✓	
Resistive Coupling	✓	✓	✓	✓	
Capacitive Coupling		✓	✓	✓	
Inductive Coupling		✓	✓	✓	
Self Impedance		✓	✓	✓	
Soil Parameters Frequency Dependance		✓	✓	✓	
Conductors with Potentials, Currents and Leakage Currents known and independent			✓		
Catenary and Bundle Conductors			✓	✓	
Propagation Effects		✓	✓	✓	
Under Ground Systems	✓	✓	✓	✓	✓
Calculation of Potentials and Touch and Step Voltages on and below the Soil Surface	✓	✓	✓	✓	
Calculation of Magnetic Fields on and above the Soil Surface		✓	✓	✓	
Calculation of Electric Fields on and above the Soil Surface			✓	✓	
Above Ground Systems			✓	✓	✓
Frequency Domain Calculation		✓	✓		✓
Time Domain Calculation				✓	
Multi-conductor / Multi-phase Systems					✓
POSSIBLE APPLICATIONS					
Grounding (equipotential systems)	✓	✓	✓	✓	
Grounding (non equipotential systems)		✓	✓	✓	
Cathodic Protection Systems		✓	✓		
Magnetic Field		✓	✓	✓	
Electric Field			✓	✓	
Electromagnetic Interferences		✓	✓	✓	
Lightning				✓	
Steady State Solver for Full Meshed Multi-conductor and Multi-phase Networks					✓
Short Circuit Current on Full Meshed Multi-conductor and Multi-phase Networks					✓
Fault Current Distribution on Full Meshed Multi-conductor and Multi-phase Networks					✓

GSA Vs GSA_FD

The following table summarizes the main assumptions on which GSA and GSA_FD modules are based.

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

The following graph represents the application domain of the two modules.
The highlighted area indicates the usual condition at power frequency.
The graph is obtained by a parametric analysis with square meshed test copper grids energized with a current injected in a corner. The analysed parameters were grid size "D" (the grid diagonal), soil resistivity "ρ" and frequency "f".
In its application dominion, the errors made by GSA in the GPR and touch voltages calculation are lower than 10%.



Application domain of GSA and GSA_FD

In practice, application limits of GSA can be defined as a function of the wavelength of the electromagnetic field in the earth:

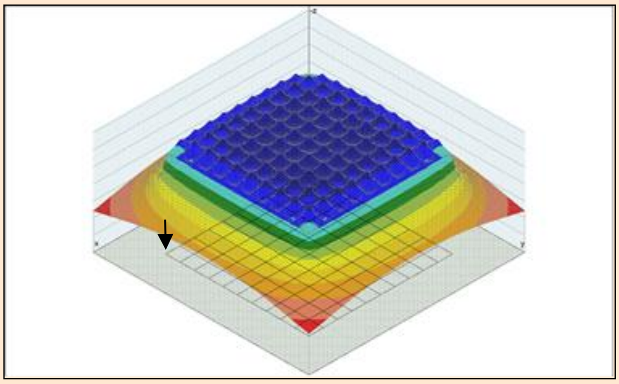
$$\lambda = 3162\sqrt{\frac{\rho}{f}}$$

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

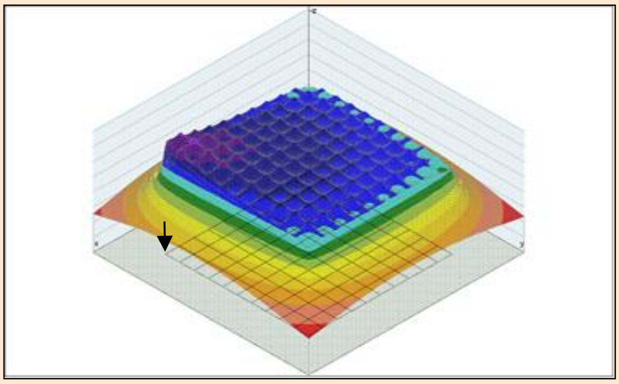
The previous graph indicates that GSA can be used if "D < λ/10". GSA also requires "D < 700 m" because the effects of the DC resistance of the copper conductors.
The application limits are lower than indicated if the grid shape is not regular, if the meshes are sparse and if the grid is made of steel.

The following figures show the earth surface potential obtained by applying GSA and GSA_FD to a 100 m x 100 m grid with the same injected current and injection point (marked with arrow) and the same soil model.
The qualitative difference between results is evident. GPR and impedance to earth tend to grow whether self impedance and mutual impedance are taken into account. High frequency or low soil resistivity can make this difference even more evident.

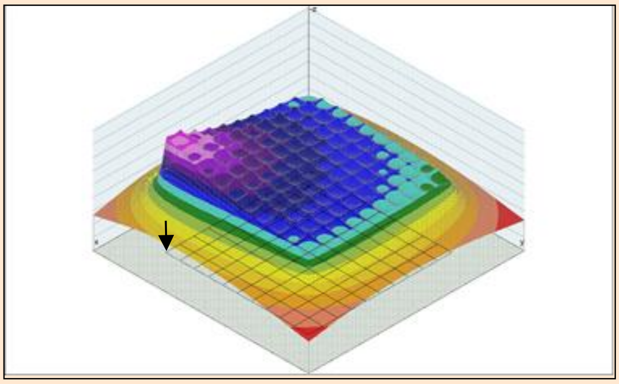
In brief, in grounding system analysis, at power frequency, GSA can be used in many practical situations but it tends to underestimate the results in case of low resistivity or large grids while GSA_FD may be applied in all cases.
At high frequency, GSA can be applied to grids with a maximum size of about some tens of meters. In general, at high frequency GSA_FD should be used.
In electromagnetic interference analysis, GSA and GSA_FD can be used respectively for only resistive and resistive + capacitive + inductive coupling evaluation.



Earth surface potential distribution - GSA (equipotential condition) - 50 Hz



Earth surface potential distribution - GSA_FD (only self impedances) - 50 Hz



Earth surface potential distribution - GSA_FD (self and mutual impedances) - 50 Hz

After these conclusions a question could arise: Why not just GSA_FD?
GSA requires an easier data entry, accept rough layouts, is cheaper and faster than GSA_FD and requires fewer computer resources.
GSA_FD requires additional information about the topology of the conductors system and in order to calculate their self and mutual impedances and a well finished layout.
Moreover GSA_FD requires a greater expertise in the evaluation of results.
If GSA cannot be used, GSA_FD is the right solution.

XGSA_FD Vs XGSA_TD

XGSA_FD is based on a model similar to GSA_FD but extended to overhead conductors network. The application limits of XGSA_FD for underground systems can be assumed as the same of GSA_FD while the application limits for overhead systems can be assumed from DC to 10 MHz.
XGSA_FD greatly expands the application field of XGSLab and it actually makes a real laboratory for engineering applications and for research.

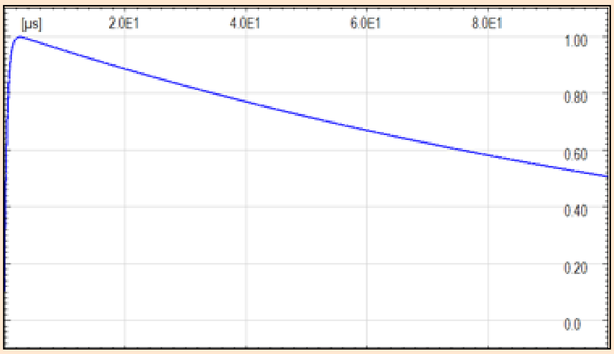
XGSA_FD is an irreplaceable tool when the conductors network is partly overhead and partly underground. This situation is usual in electromagnetic fields evaluation (where sources may be underground cables or overhead wires) or interference analysis (where often the inductor is overhead and the induced is underground).
XGSA_FD is useful also for the evaluation of the fault current distribution.
Furthermore, XGSA_FD may be used also in lightning design by using an equivalent single frequency sinusoidal input signal (see literature). For instance, the IEC 62305 standard first positive stroke T_1/T_2 = 10/350 µs can be simulated with a 25 kHz current, the first negative stroke 1/200 µs with a 250 kHz current and the subsequent stroke 0.25/100 µs with a 1 MHz current.

XGSA_TD can calculates the response in the time domain of a conductors network energized with a current or voltage transient.

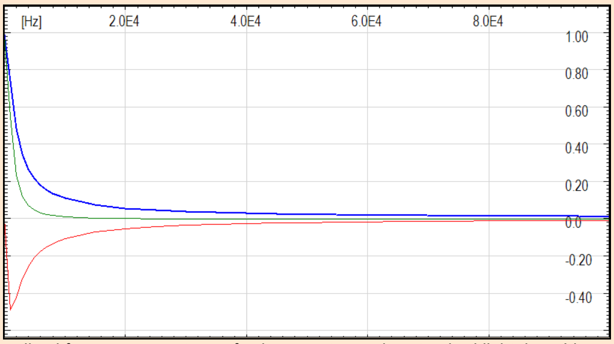
As known, the methods to calculate the transient behaviour of conductors network in the time domain can be divided into two main categories: those based on the calculation of the solution directly in the time domain and those based on frequency domain calculations and then using the forward and inverse Fourier transforms.
Methods of the first category require low frequency and quasi-static approximations and in addition do not allow considering the frequency dependent characteristics of the grounding system.
Methods of the second category use an electromagnetic field approach for the calculation of the response of the grounding system in a wide range of frequencies and have a good accuracy because they are based strictly on the principles of electromagnetism. On the other hand, in these methods, a system of equations has to be solved for every particular frequency, and a large number of discrete frequency points over the frequency band are chosen to satisfy the frequency sampling theorem.

XGSA_TD is based on the second category methods and uses XGSA_FD as solver in the frequency domain. Then the application limits of XGSA_TD can be assumed as the same of XGSA_FD and in particular the maximum bandwidth of the input transient should be lower than 10 MHz.
This means that XGSA_TD can consider transient input as standard lightning currents.
The lightning current can be simulated by using the standard short stroke wave form IEC 62305: First positive; First negative; Subsequent negative.

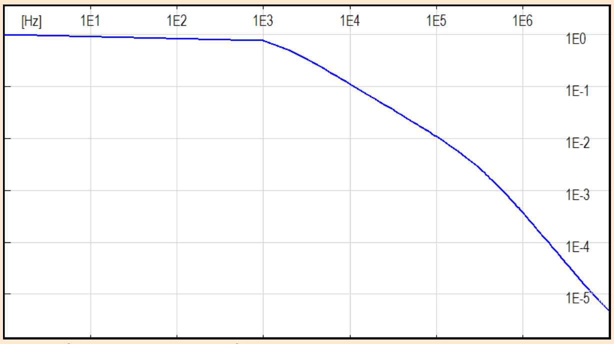
With the direct Fourier transform the time domain input transient is decomposed in the frequency domain.
In the following figures the normalized wave shape of the subsequent negative standard lightning current and their normalized frequency spectrum. The spectrum can be neglected when normalized values are lower than about 10^{-4} - 10^{-5}. The standard lightning bandwidth is lower than a few MHz also for the most fast lighting, the subsequent negative ones.



Normalized subsequent negative standard lightning



Normalized frequency spectrum of subsequent negative standard lightning - Linear



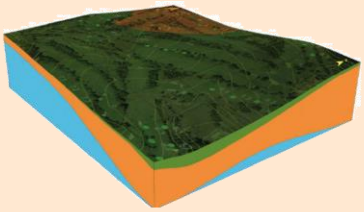
Normalized frequency spectrum of subsequent negative standard lightning – Log-Log

After the calculation in the frequency domain (taking into account a reduced number of critical frequencies in order to limits the calculation time), the response in the time domain is obtained with the inverse Fourier transform.

The evaluation of lightning effects is important in many practical applications.
For instance, current generated by a stroke flows in the LPS conductors and dissipate in the soil. The electric and magnetic field generated by such high voltages and currents can cause internal discharges, fires and explosions, may cause damage of equipment and buildings and may be dangerous for people.

UNIFORM, MULTILAYER AND MULTIZONE SOIL MODELS

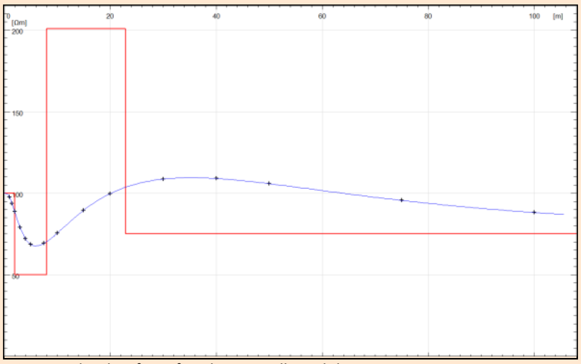
The choice of the soil model is crucial in electromagnetic simulations and in particular in the grounding systems analysis. There is much literature about the criteria to set an appropriate soil model which can be used to predict the performances of a grounding system. XGSLab allows to use uniform, multilayer and multizone soil models.



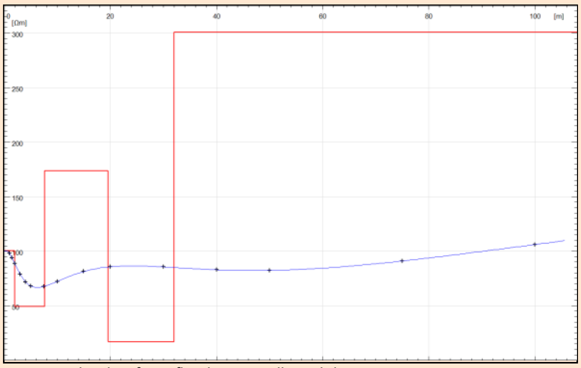
A typical soil cross section including ground water

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 and the presence of ground water further complicates things. 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, four or five layers can be sufficient for most cases.



Parameters evaluation for a four layers soil model



Parameters evaluation for a five layers soil model

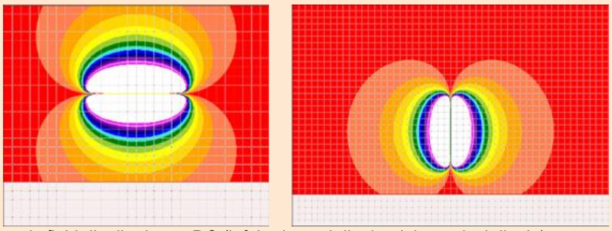
In case of grounding systems of intermediate size, soil model is affected by both horizontal and vertical changings in soil resistivity and usually an equivalent double or triple layer soil model is appropriate. This is the most important case in practical applications.
In case of large grounding systems (maximum size over a few kilometres), 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 EARTH REACTION

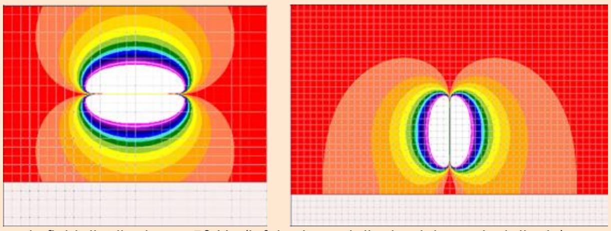
The earth reacts to the AC electromagnetic.
The exact solution of this problem was found by Sommerfed and involves integrals (known as Sommerfeld integrals) that represent the solution of the Maxwell equations related to infinitesimal horizontal or vertical current elements radiating in the presence of a lossy half space. Sommerfeld integrals take into account the boundary conditions on the tangential components of the electromagnetic fields at the half space interface.
These integrals usually cannot be solved in closed form and in general are quite difficult to calculate also with a numerical approach because contain very oscillating Bessel functions.

The earth reaction to the AC electromagnetic fields grows with frequency and soil conductivity and is different for horizontal and vertical and moreover buried or aerial sources.

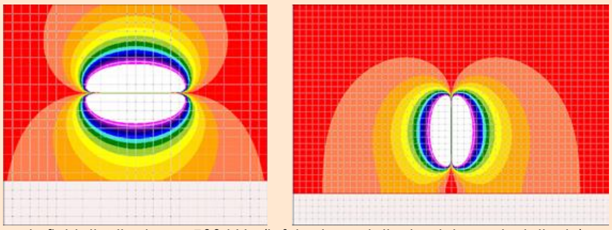
In order to display the earth reaction in an effective way, in the following, is represented the cross section of the magnetic field close an horizontal or vertical source on or above the soil surface.
In DC condition there is no earth reaction.
At low frequency the earth reaction is negligible for horizontal sources but significant for vertical sources.
At high frequency, the earth reaction becomes always relevant and the earth acts as a mirror for the magnetic field. With vertical sources this happen also at relatively low frequency.
Far from the source, the earth reaction is significant also at low frequency.



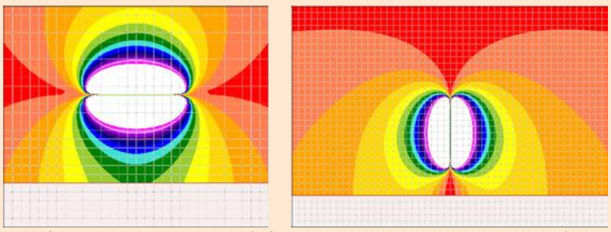
Magnetic field distribution at DC (left horizontal dipole, right vertical dipole)



Magnetic field distribution at 50 Hz (left horizontal dipole, right vertical dipole)



Magnetic field distribution at 500 kHz (left horizontal dipole, right vertical dipole)



Magnetic field distribution at 5 MHz (left horizontal dipole, right vertical dipole)

APPLICATIONS OF THE DIFFERENT MODULES

The following table summarizes the main applications of the available modules.

Application	GSA	GSA_FD	XGSA_FD
Grounding (small systems)	Yes	Yes	Yes
Grounding (large systems)		Yes	Yes
Cathodic Protection Systems		Yes	Yes
Magnetic Field		Yes	Yes
Electric Field			Yes
Electromagnetic Interferences		Yes	Yes
Fault Current Distribution			Yes
Lightning effects for a single frequency			Yes

XGSA_TD can be applied in order to analyse in the time domain current and potential distribution on underground and/or overhead conductors network energized by means current or voltage transient and can calculate the consequent distributions of earth potentials and electric and magnetic fields.

NETS is a tool based on circuit theory and then it is completely different form the other modules XGSLab modules based on the electromagnetic fields theory. NETS can solve full meshed multi-conductor and multi-phase networks composed of multi-port cells connected by means of multi-port buses. NETS can calculate potentials and currents in all ports in steady state or fault conditions and in particular can be used for the calculation of the fault current distribution in power networks.

FAQ

Is XGSLab easy to use?

Very easy with basic applications, as for instance for grounding systems analysis with GSA. Advanced applications requires an adequate knowledge of the matter but anyway XGSLab User's Guide and Tutorial can help also beginners.

How is XGSLab delivered?

XGSLab requires a USB protection dongle shipped via courier. Delivery time is usually in the range 2 – 4 working days. The program can be downloaded from our helpdesk.

How is XGSLab licensed?

XGSLab single user license may be installed in any number of PC's but only the PC with the USB dongle attached may be in used.

Does XGSLab is available as network license?

Yes, it is. In this case the USB protection dongle has to be plugged in a server of the local network. The network license allows to use XGSLab on the local network simultaneously by a number "N" of users depending on agreements. User "N+1" can use XGSLab when one of the active users stops running the licensed software.

Does XGSLab includes a support period?

XGSLab includes 12 months of support period. The support includes software and documents updating, maintenance support and regular engineering applications support. The support period may be renewed on an annual basis.

What are software and hardware requirements?

XGSLab can works with Windows 7 or upper (10 included) 32 or 64 bit and requires Microsoft.NET Framework 4.5 installed.
RAM requirements depend on the applications. Usually 2 GB are sufficient for NETS and for basic applications with other modules but large systems can require up to 32 GB. Install Windows on your MAC to use XGSLab.

THE GREAT THINKERS

XGSLab is based on Maxwell equations, Green functions and Sommerfeld integrals.
Most people know that the electromagnetic field are governed by a set of experimental laws known as Maxwell equations.
On the other hand, not many people know about the fundamental studies carried out by Green and Sommerfeld.

Jean-Baptiste Joseph Fourier
(Auxerre 1768 – Paris 1830)

George Green
(Nottingham 1793 – Nottingham 1841)

James Clerk Maxwell
(Edinburgh 1831 – Cambridge 1879)

Arnold Johannes Wilhelm Sommerfeld
(Konigsberg 1868 – Munich 1951)

George Green (UK 1793 –1841) studied the solution of inhomogeneous differential equations and the so called Green functions are fundamental solutions of these equations satisfying homogeneous boundary conditions. XGSLab implemented the Green functions to calculate the scalar potential of a point charge in a multilayer soil models.
Sommerfeld studied the earth reaction to the electromagnetic field and the rigorous solutions of the half space problem are known as Sommerfeld integrals, XGSLab implemented the Sommerfeld integrals for the calculation of the vector potential of horizontal or vertical electric dipoles in a multilayer soil models.
Without Green and Sommerfeld studies would not have been possible to develop XGSLab.

Furthermore, the calculation in the time domain were been possible by using the Fourier transforms. Fourier transforms allow moving from the time domain and viceversa.

XGSLab is based on the research of many other scientists as for instance Leonhard Euler (1707 – 1783) and Johann Friedrich Carl Gauss (1777 – 1855).
It is important to remember these great thinkers of the past but it is also important to be grateful to all mathematician that in more recent times have improved the scientific computing.

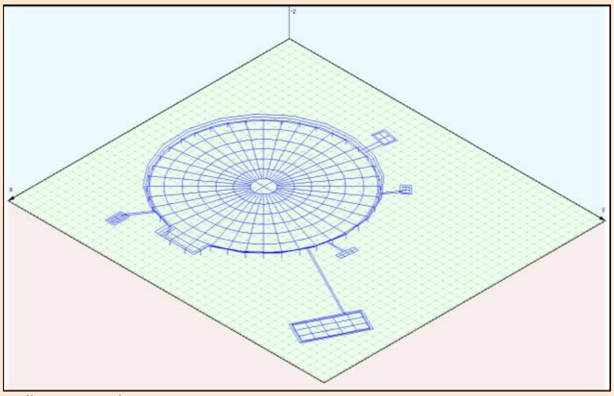
GROUNDING SYSTEM ANALYSIS

GSA is an Engineering Software for Earth Grid Calculations and Design including Soil Resistivity Analysis. GSA has been adopted worldwide by many Universities and Organisations and is highly appreciated by our clients for its Ease of Use, Quality and Technical Support Services.

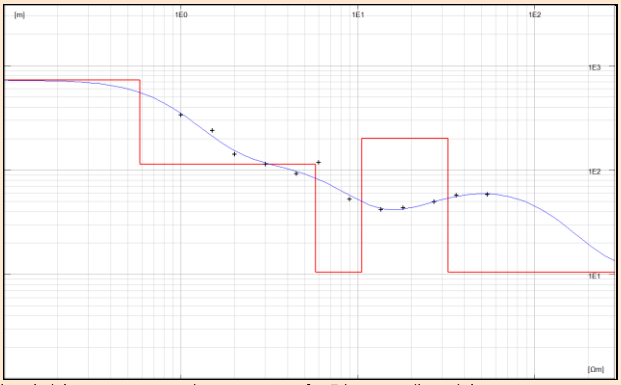
GENERAL DESCRIPTION

GSA is a computation code for design and analysis of low frequency grounding systems. GSA takes into account International (IEC/TS 60479-1:2005), European (EN 50522:2010) and American (IEEE Std 80-2000 and IEEE Std 80-2013) standards.

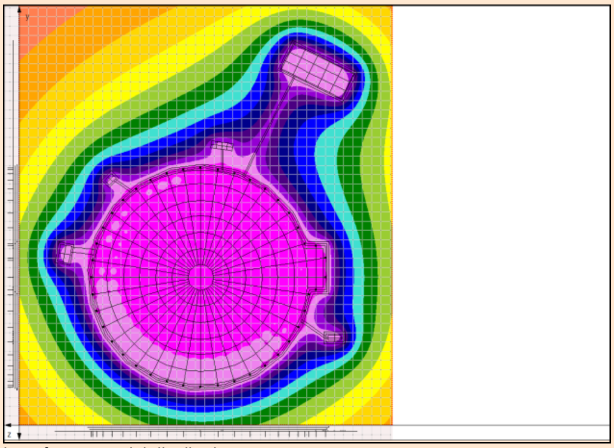
GSA is able to analyse the low frequency performance of earthing systems composed of more distinct electrodes of any shape, with a high level of details. It can take input data in the form of either graphical (from "dxf" files or from the integrated CAD) or numerical and render powerful graphical facilities via it's optimised and validated computation algorithms, thus making GSA an indispensable tool for grounding system design and verification.
GSA includes the module SRA to calculate uniform or multilayer soil model parameters starting from measured soil resistivity data.
GSA is essentially a low frequency tool but in several practical cases (with little electrodes), it can be also useful to calculate the impulse impedance of electrodes under lighting currents with an accuracy level adequate for many engineering applications.



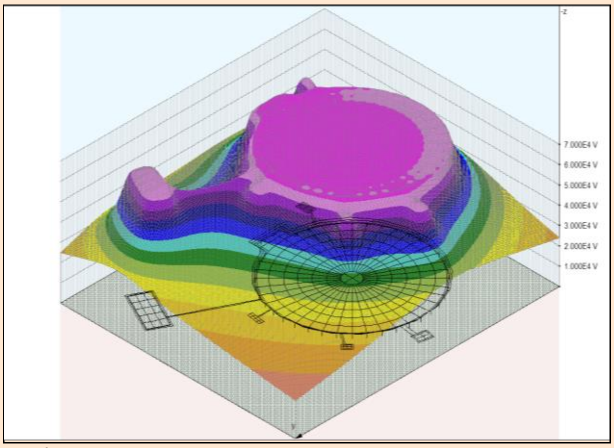
Grounding system layout



Soil resistivity measures and parameters of a 5 layers soil model



Earth surface potential distribution



Earth surface potential distribution

INPUT DATA

- Electrical data (e.g. single phase to earth fault current, data for calculation of earthing current, reference standard, intervention time of protections, eventually additional resistance between feet and earth surface or gloves, etc.)
- Geometrical data (e.g. grounding system layout of all electrodes (up to 99), conductors section, coating thickness, material properties, etc.). Each electrode consists in a network of arbitrarily connected (or separated) conductors
- Physical data (e.g. soil resistivity or apparent resistivity measured values, superficial thin layer characteristics, etc.)

OUTPUT RESULTS

- Decrement factor (Df) as per IEEE standard
- Split factor (r) as per EN standard or (Sf) as per IEEE standard
- Earthing current
- Minimum cross section of grounding system conductors for thermal specification
- Uniform or multilayer soil model parameters from on site measures values of apparent resistivity with Wenner or Schlumberger methods
- Reduction factor of touch and step voltages due to a superficial thin layer (Cs) as per IEEE standard
- Maximum permissible touch and step voltages as per IEC, EN and IEEE standards taking into account the body resistance and possibly additional resistance (shoes, gloves …). With IEC and EN standards both, prospective and permissible values of touch and step voltages are given
- Ground resistance and Ground Potential Rise values of all electrodes
- Distribution of leakage current from the electrodes with 1D, 2D and 3D graphical representation to verify the efficiency of specific grounding system parts
- Maximum electric field value close to the electrodes (useful to quickly check if the soil ionization phenomenon can occur)
- Earth potentials and prospective and effective touch and step voltages distributions on straight lines or rectangular areas lying on or below the soil surface by 2D and 3D coloured graphic representations, for individuation of safe and hazardous areas
- List of material used for grounding system (wires and rods)
- Orthographic projections or isometric representations of grounding system

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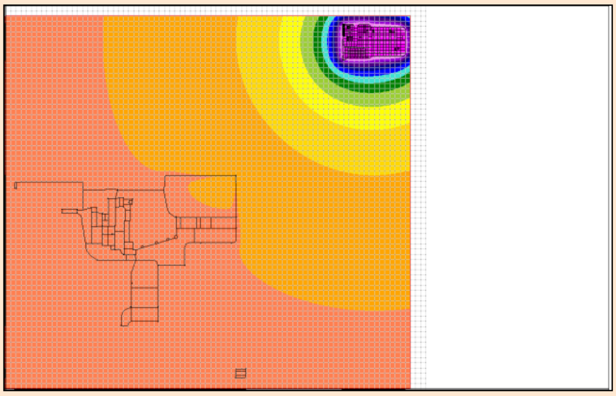
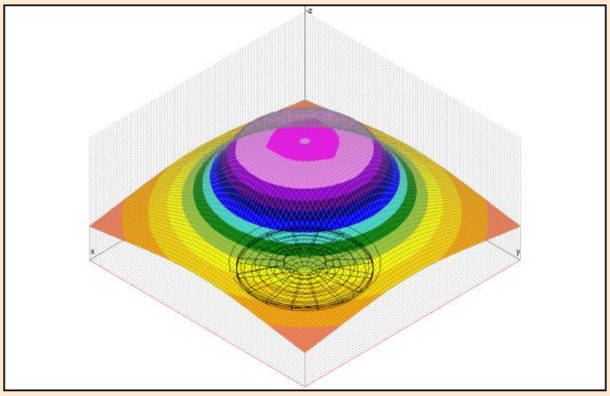
ONE STEP AHEAD



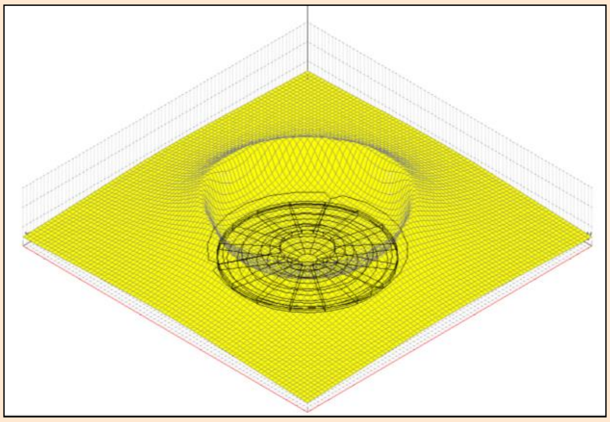
Earth surface potential distribution in the presence of a floating electrode



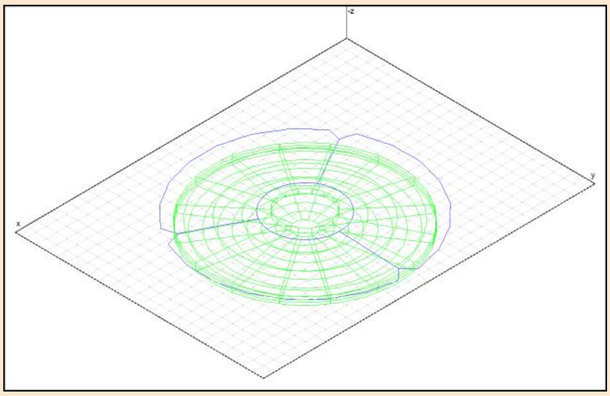
Earth surface potential distribtion

MAIN FEATURES

- Calculation model based on "PEEC" method
- Automatic debug of data before calculation
- Analysis of grounding systems of any shape, with choice of the total number of elementary sources
- Possibility to analyse up to 99 distinct electrodes on the same calculation, including for instance return electrodes, transmission line grounding systems or floating potential underground electrodes
- Characterization of soil with a uniform or multilayer model. Beyond this a superficial thin layer can be added
- Possibility to analyse electrodes partially insulated or encased in concrete or buried in treated soil to lower resistivity
- Libraries with typical properties of soil, soils covering, concrete and backfill materials
- Possibility to export layout data and results in .dxf file
- Possibility to export graphic outputs to other WINDOWS® applications
- Possibility to choose the language (English, German. French, Italian, Spanish)



Step voltages distribution



Grounding system layout of a wind tower

GSA FD

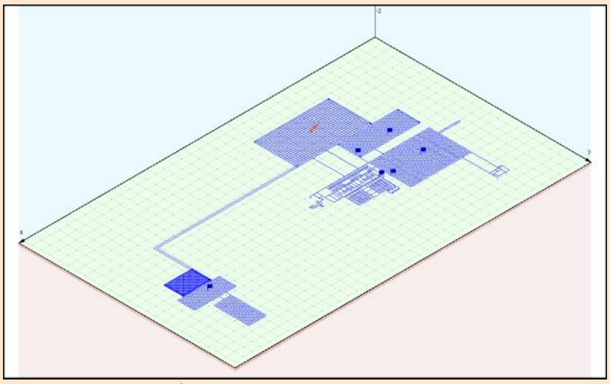
GROUNDING SYSTEM ANALYSIS in the FREQUENCY DOMAIN

GSA_FD is an Engineering Software for Earth Grid Calculations and Design in the frequency domain from DC to 10 MHz including Soil Resistivity Analysis.
GSA_FD is useful in all cases where the hypothesis of equipotential condition of the electrode is not acceptable. This happens with either large grounding systems, low soil resistivity, steel conductors or high frequency. GSA_FD takes into account both self and mutual impedance effects.

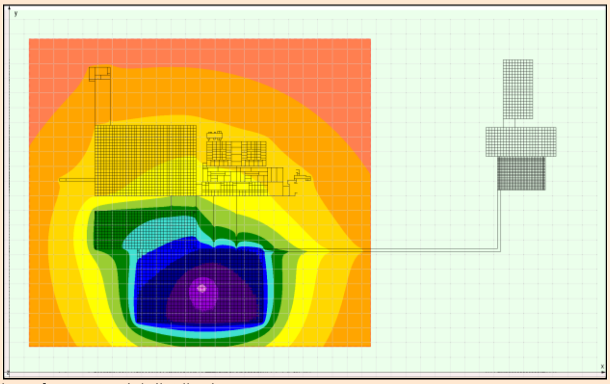
GENERAL DESCRIPTION

GSA_FD is a computation code for design and analysis of grounding systems in the frequency domain from DC to 10 MHz. GSA_FD takes into account International (IEC/TS 60479-1:2005), European (EN 50522:2010) and American (IEEE Std 80-2000 and IEEE Std 80-2013) standards.
GSA_FD takes into account the frequency dependence of soil parameters and allows setting the used model choosing from the most established.

GSA_FD is able to analyse the frequency domain performance of extensive earthing systems composed of more distinct electrodes of any shape and size with a high detail level. The graphical (from “dxf” files or from the integrated CAD) and numerical input data, the optimised and validated computation algorithms, the powerful graphical facilities render GSA_FD an indispensable tool for grounding system design and verification, when the drop voltage on conductors cannot be ignored. Moreover, GSA_FD takes into account both self and mutual impedance of the conductors.
GSA_FD includes the module SRA to calculate uniform or multilayer soil model parameters starting from measured soil resistivity data.
GSA_FD can also consider a multizone sol model. A multizone soil model should be used when the size of the conductors network is so large than the horizontal soil resistivity changing are more significant than vertical variations.
The buried electrodes can be realized with solid, hollow or stranded and coated or bare conductors connected in an arbitrary way.



Grounding system layout of a large plant

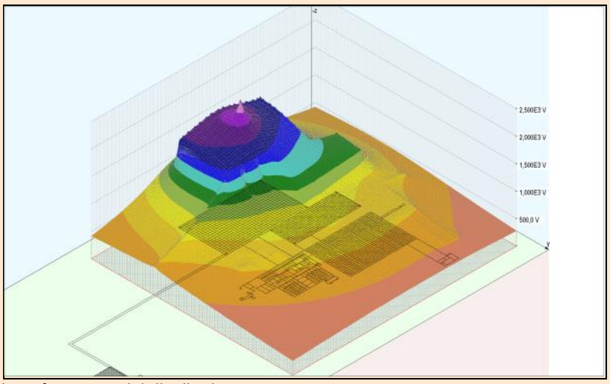


Earth surface potential distribution

GSA_FD is one of the most powerful and general software on the market for grounding system analysis and can be used to solve electromagnetic compatibility or interference problems due to resistive, capacitive and inductive coupling in the earth.

In DC conditions GSA_FD can be used for the cathodic protection and anode bed analysis, with impressed current systems involving extensive coated and uncoated buried structure.

GSA_FD is also useful to calculate magnetic field due to grounding systems or buried cables and can be used to investigate the effectiveness of passive loop mitigation systems.



Earth surface potential distribution

INPUT DATA

- Electrical data (e.g. injected current or specified potential in an arbitrary number of points, impressed or induced EMF, operative frequency, additional longitudinal impedances, reference standard, intervention time of protections, eventually additional resistance between feet and earth surface or gloves, etc.)
- Geometrical data (e.g. grounding system layout and topology of all electrodes (up to 99), conductors section, coating thickness, material properties, etc.). Each electrode consists in a network of arbitrarily connected (or separated) conductors
- Physical data (e.g. soil resistivity or apparent resistivity measured values, soil electrical permittivity, superficial thin layer characteristics, etc.)

OUTPUT RESULTS

- Decrement factor (Df) as per IEEE standard
- Split factor (r) as per EN standard or (Sf) as per IEEE standard
- Earthing current
- Minimum cross section of grounding system conductors for thermal specification
- Uniform or multilayer soil model parameters from on site measures values of apparent resistivity with Wenner or Schlumberger methods
- Reduction factor of touch and step voltages due to a superficial thin layer (Cs) as per IEEE standard
- Maximum permissible touch and step voltages as per IEC, EN and IEEE standards taking into account the body resistance and possibly additional resistance (shoes, gloves …). With IEC and EN standards both, prospective and permissible values of touch and step voltages are given
- Ground impedance and Ground Potential Rise of all reference points (ground impedance is calculated as ratio between its GPR of the specific point and the total injected current in the electrodes)
- Distribution of leakage current from the electrodes with 1D (magnitude, real and imaginary), 2D and 3D graphical representation to verify the efficiency of cpecific grounding system parts
- Maximum electric field value close to the electrodes (useful to quickly check if the soil ionization phenomenon can occur)
- Distribution of longitudinal current (transferred or induced) on the electrodes with 1D (magnitude, real and imaginary), 2D and 3D graphical representation
- Distribution of potential (transferred or induced) on the electrodes with 1D (magnitude, real and imaginary), 2D and 3D graphical representation
- Distribution of electromotive force on the electrodes with 1D (magnitude, real and imaginary), 2D and 3D graphical representation
- Distribution of complex power on the electrodes with 1D (magnitude, real and imaginary), 2D and 3D graphical representation
- Earth potentials and prospective and effective touch and step voltages distributions on straight lines or rectangular areas lying on or below the soil surface by 2D and 3D coloured graphic representations, for individuation of safe and hazardous areas

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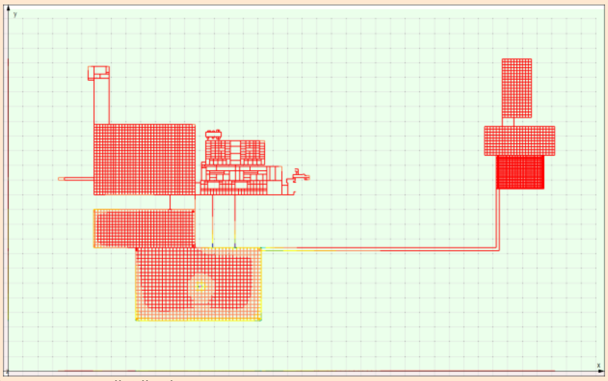
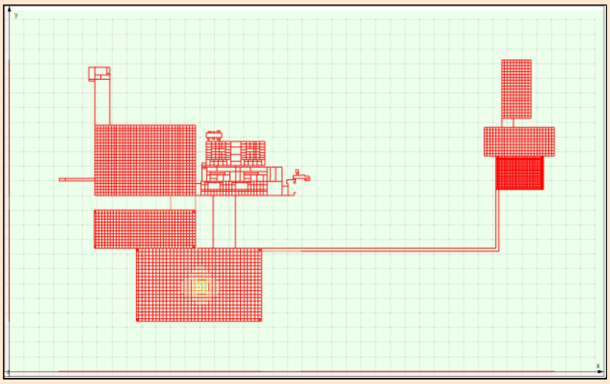
ONE STEP AHEAD

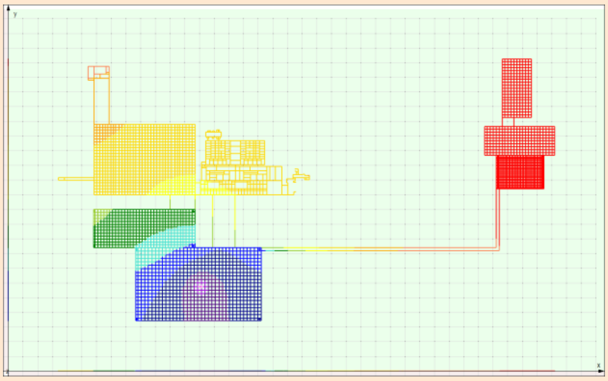
- Magnetic field distributions on horizontal straight line or rectangular area with 1D, 2D and 3D coloured graphic representations, for individuation of safe and hazardous areas
- List of material used for grounding system (wires and rods)
- Orthographic projections or isometric representations of grounding system



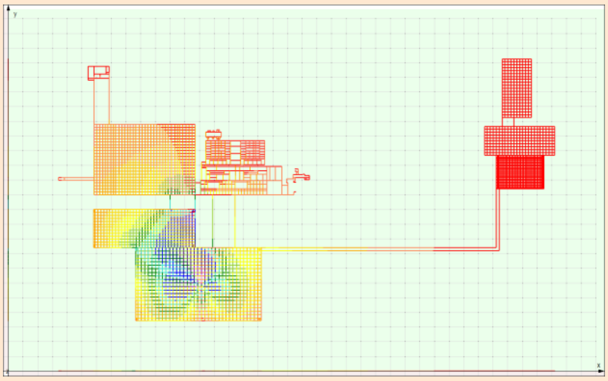
Leakage currents distribution



Longitudinal currents distribution

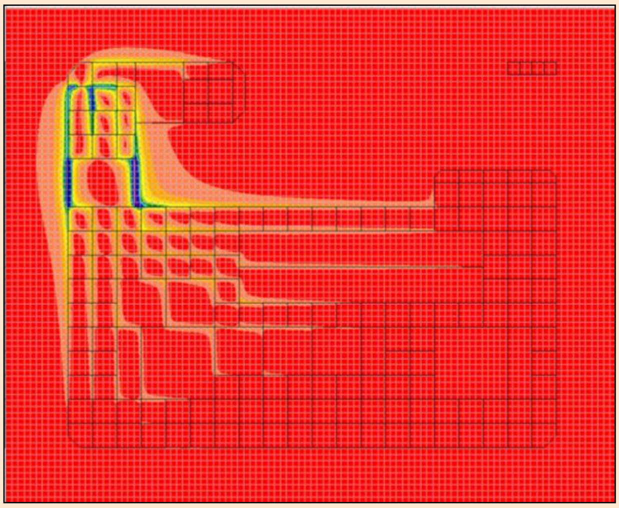


Potential distribution

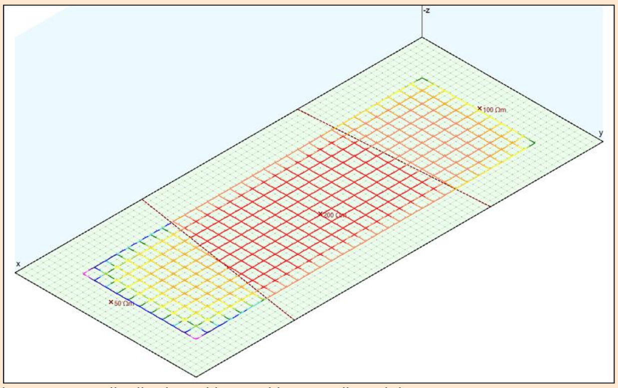


EMF distribution

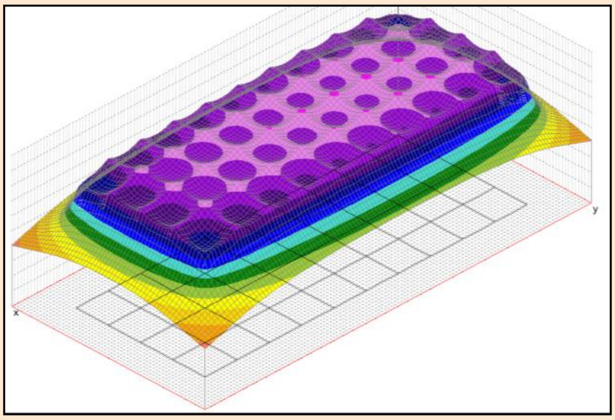
Touch and Step voltages safe areas



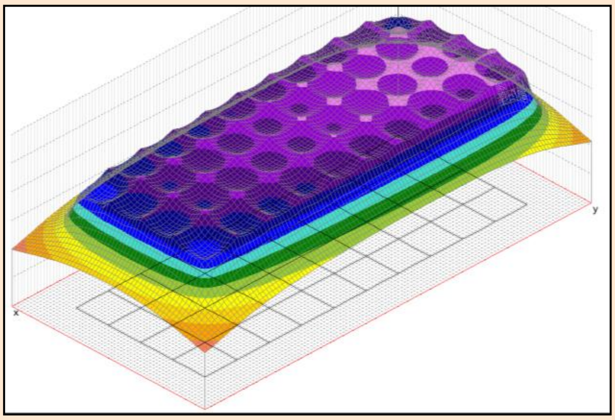
Magnetic field distribution in case of fault to earth



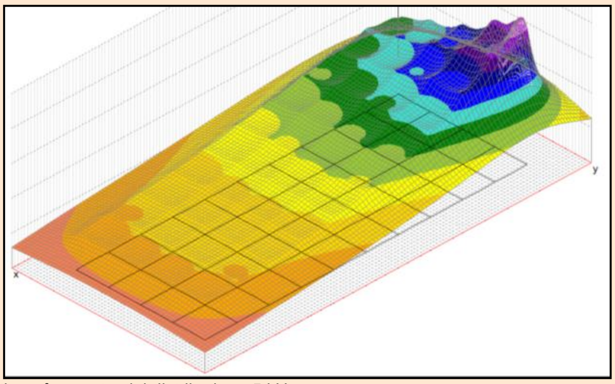
Leakage current distribution with a multizone soil model



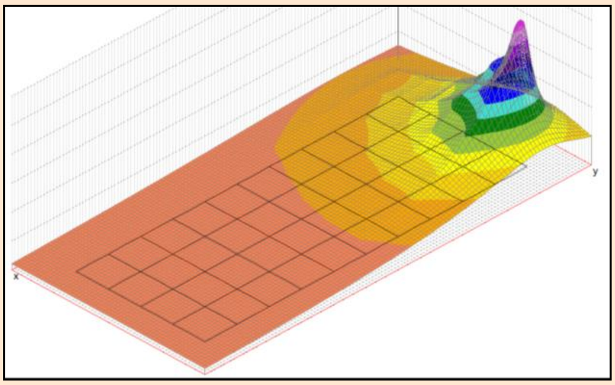
Earth surface potential distribution - 50 Hz



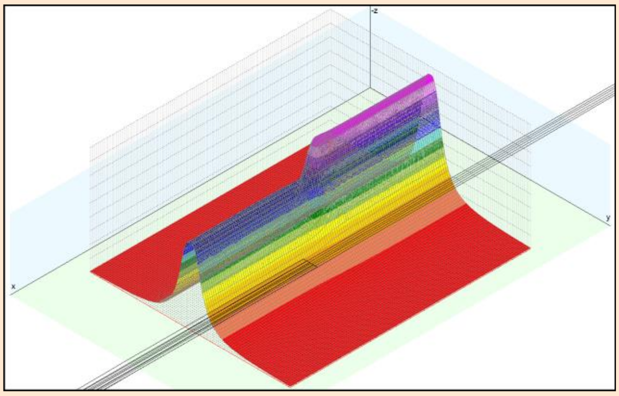
Earth surface potential distribution - 500 Hz



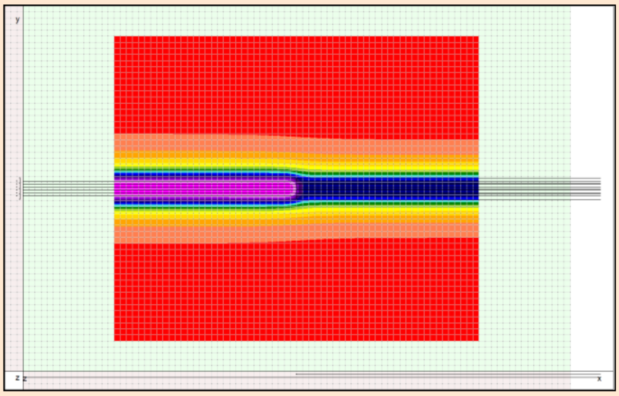
Earth surface potential distribution - 5 kHz



Earth surface potential distribution - 50 kHz



Magnetic field distribution - Mitigation with a passive loop



Magnetic field distribution - Mitigation with a passive loop

MAIN FEATURES

- Calculation model based on “PEEC” method
- Analysis of grounding systems of any shape, with choice of the total number of elementary sources
- Possibility to analyse up to 99 distinct electrodes on the same calculation, including for instance return electrodes, transmission line grounding systems or floating potential underground electrodes
- Automatic recognition of the connections between conductors
- Characterization of soil with a uniform or multilayer model. Beyond this, a superficial thin layer can be added
- Possibility to analyse electrodes buried in a multizone soil model
- Possibility to analyse electrodes partially insulated or encased in concrete or buried in treated soil to lower resistivity
- Libraries with typical properties of soil, soils covering, conductors and insulating materials
- Possibility to export layout data and results in .dxf file
- Possibility to export graphic outputs to other WINDOWS® applications
- Possibility to choose the language (English, German. French, Italian, Spanish)

SINT Ingegneria
ONE STEP AHEAD

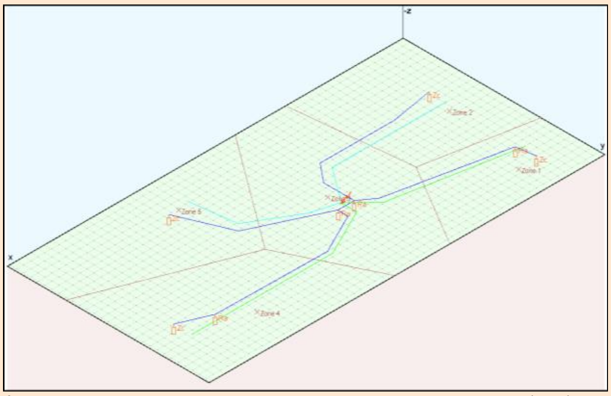
OVER AND UNDERGROUND SYSTEM ANALYSIS in the FREQUENCY DOMAIN

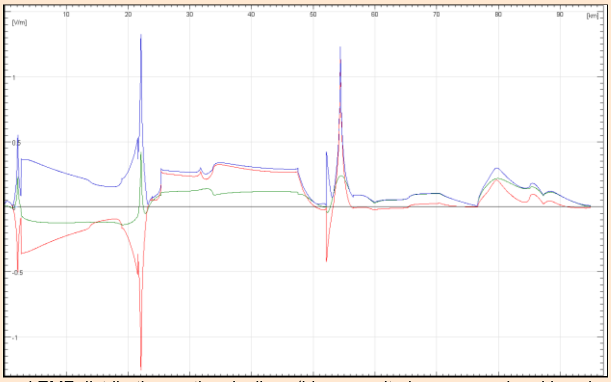
XGSA_FD is a multipurpose Engineering Software for Grounding Systems, Electromagnetic Field and Interference Analysis and Fault Current Distribution in the frequency domain from DC to 10 MHz including Soil Resistivity Analysis. XGSA_FD uses a calculation model similar to GSA_FD but extended to overhead systems and considers also sources where potential and longitudinal current are known and independent by other conditions.

GENERAL DESCRIPTION
XGSA_FD is a computation code for grounding systems, electromagnetic field and interference analysis in the frequency domain from DC to 10 MHz.

XGSA_FD uses a model similar to GSA_FD and referring to underground electrodes the two models can be considered the same.
XGSA_FD extends the GSA_FD application field to the overhead systems and can manage straight or catenary spans of single or bundle conductors (solid, hollow or stranded and coated or bare), and can take into account sources where potential or leakage current and longitudinal current are known and independent by other conditions.
The underground or overhead conductors can be connected in an arbitrary way.

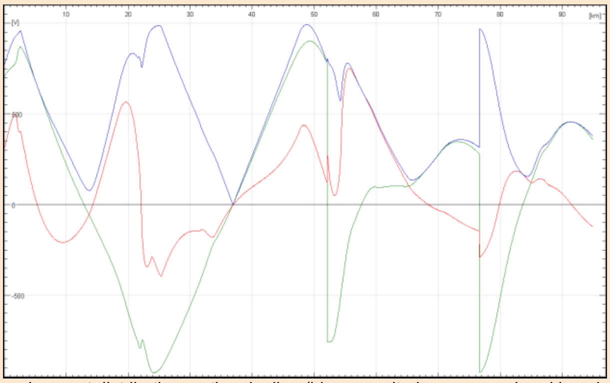
XGSA_FD is a multipurpose software and its use is not limited to specific cases. XGSA_FD application field includes grounding system analysis but is oriented in particular way to solve electromagnetic compatibility or interference problems due to resistive, capacitive and inductive coupling in air or in the earth.
For instance, XGSA_FD can evaluate electromagnetic interference between overhead or underground power lines and installation as pipelines, railways or communications lines.
XGSA_FD can calculate the effects of lightning for a single frequency and also the fault current distribution.
XGSA_FD is also useful to calculate magnetic and electric field due to underground or overhead electrodes (grounding systems, buried cables, overhead power lines) and can be used to investigate the effectiveness of passive loop mitigation systems.

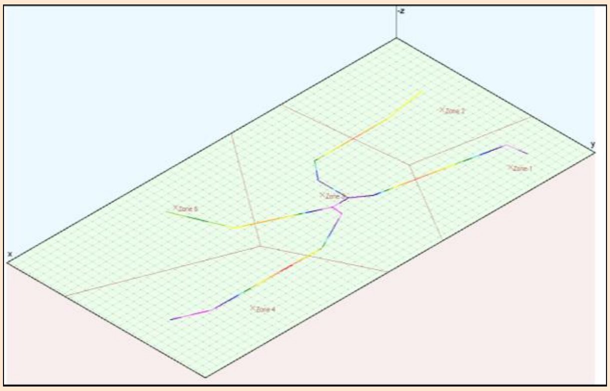

Interference layout between overhead power lines and pipeline network (blue)


Induced EMF distribution on the pipelines (blue magnitude, green real, red imaginary)

INPUT DATA
As for GSA_FD and moreover:
- Additional Electrical data (e.g. conductors with potential and longitudinal current known and independent by other conditions, additional longitudinal and transverse impedances, etc.)
- Additional Geometrical data (e.g. overhead system layout and topology of all electrodes (up to 99), catenary constant, bundle diameter, bundle conductors number, conductor conductors section, coating thickness, material properties etc.). Each electrode consists in a network of arbitrarily connected (or separated) conductors

OUTPUT RESULTS
As for GSA_FD and moreover:
- Distribution of leakage current, longitudinal current, potential, electromotive force and complex power on the overhead electrodes with 1D (magnitude, real and imaginary), 2D and 3D graphical representation
- Magnetic field distributions on arbitrarily oriented straight line or horizontal or vertical rectangular area with 1D, 2D and 3D coloured graphic representations, for individuation of safe and hazardous areas
- Magnetic flux across horizontal or vertical rectangular areas, for individuation of induced EMF and evaluation of separation distance
- Electric field distributions on arbitrarily oriented straight line or horizontal or vertical rectangular area with 1D, 2D and 3D coloured graphic representations, for individuation of safe and hazardous areas


Induced current distribution on the pipeline (blue magnitude, green real, red imaginary)


Induced potential distribution on the pipeline

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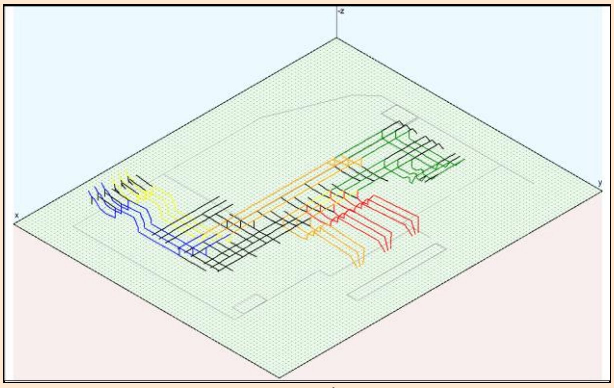
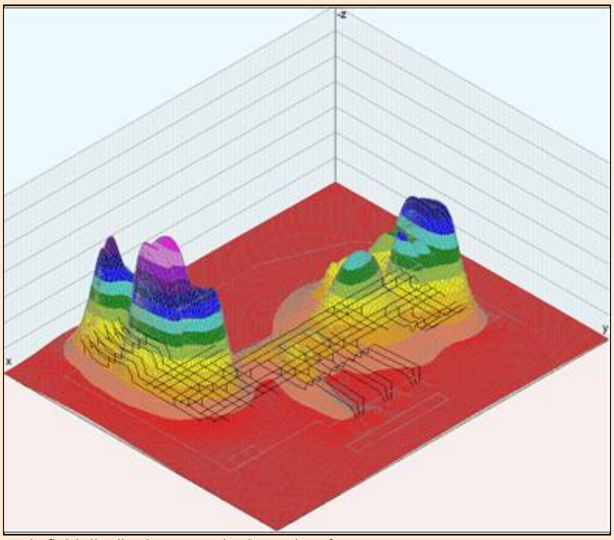
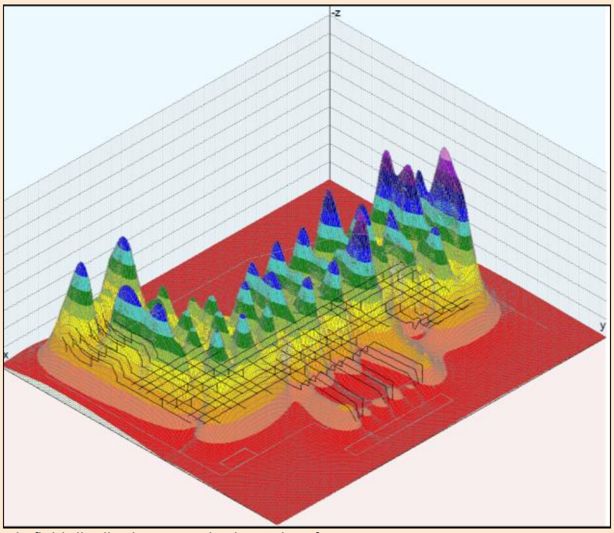
ONE STEP AHEAD



Currents distribution on the main conductors of an electrical substation



Magnetic field distribution on an horizontal surface

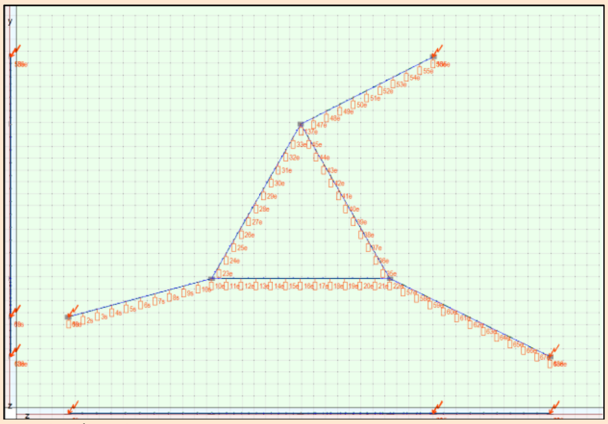


Electric field distribution on an horizontal surface

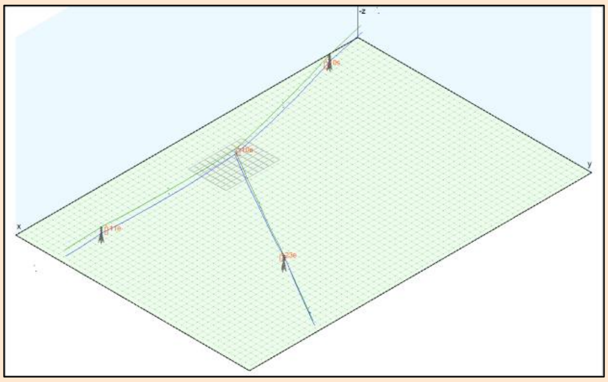
MAIN FEATURES

As for GSA_FD and moreover:

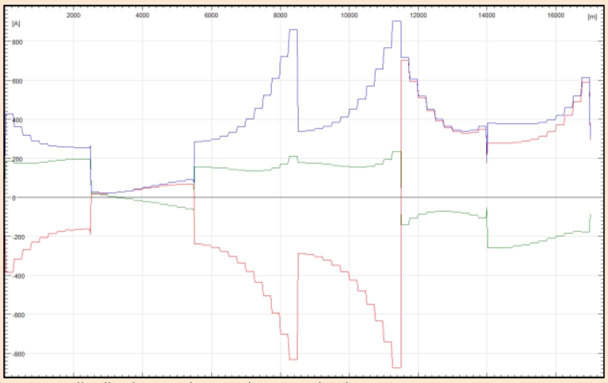
- Analysis of overhead and underground systems of any shape, with choice of the total number of elementary sources
- Possibility to analyse up to 99 distinct overhead and underground electrodes on the same calculation
- Possibility to take into account sources where potential and longitudinal current are known and independent by other conditions
- Possibility to analyse overhead straight or catenary spans of single or bundle conductors



Power system layout



Power system layout – Detail



Fault current distribution on the overhear earth wires

OVER AND UNDERGROUND SYSTEM ANALYSIS in the TIME DOMAIN

XGSA_TD is a multipurpose Engineering Software for the analysis of conductors network in the time domain taking into account transients with maximum bandwidth lower than 10 MHz including Soil Resistivity Analysis and Fourier Analysis. XGSA_TD uses the "frequency domain approach" and XGSA_FD as solver. Then also XGSA_TD can take into account both underground and overhead conductors network.

GENERAL DESCRIPTION

XGSA_TD is a computation code for the analysis of underground and/or overhead conductors network in the time domain taking into account transients with maximum bandwidth lower than 10 MHz.

XGSA_TD uses the "frequency domain approach" and XGSA_FD as solver. Then XGSA_TD extends the XGSA_FD application field to time domain.

As for XGSA_FD, also XGSA_TD is a multipurpose software and its application field includes power, grounding and lightning protection system analysis.
For instance, XGSA_TD can evaluate the distribution of the lightning stroke currents along lightning protection system (underground and overhead components) and also the related potential, electromotive force and leakage current distributions in the time domain.
XGSA_TD is also useful to calculate magnetic and electric fields due to underground or overhead electrodes in the time domain.

INPUT DATA

As for XGSA_FD and moreover:

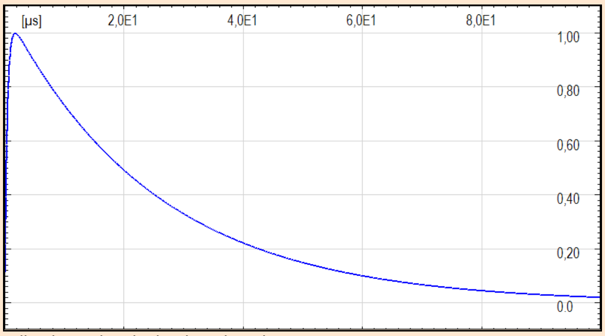
- Parameters of the normalized transient function (Double Exponential, Pulse or Heidler functions)

OUTPUT RESULTS

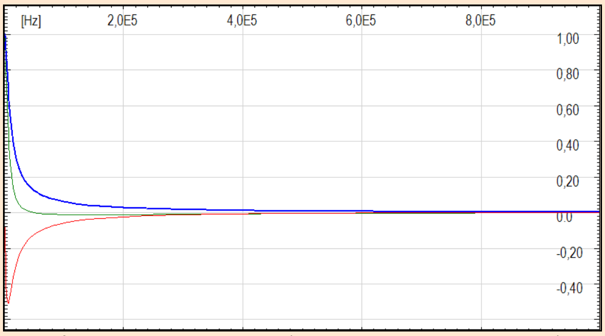
XGSA_FD provides the time domain distribution and the frequency spectrum of the input transient (linear and Log – Log plot).
XGSA_TD results are as for XGSA_FD but in the time domain.
Calculations of earth potentials, touch and step voltages, electric and magnetic fields are possible along lines.

It is possible to represents:

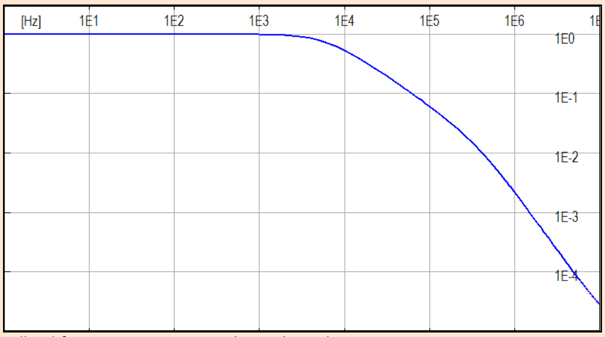
- The time domain distribution of leakage current, longitudinal current, potential, electromotive force and complex power in each point on the electrodes with 1D representation
- The time domain distribution of earth potentials, touch and step voltages, electric and magnetic fields in each point of a line calculation
- The distribution of earth potentials, touch and step voltages, electric and magnetic fields along an entire line calculation at a fixed time
- The animation of the time domain distribution of earth potentials, touch and step voltages, electric and magnetic fields along an entire line calculation



Normalized transient in the time domain



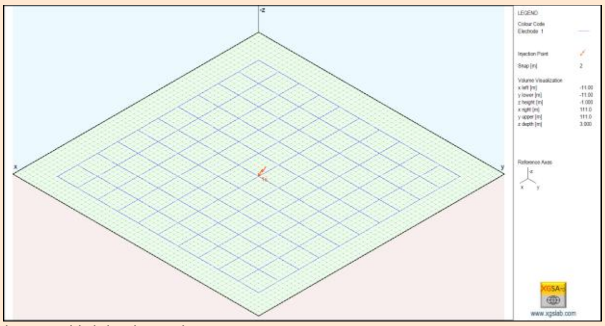
Normalized frequency spectrum – Linear (modulus, real and imaginary parts)



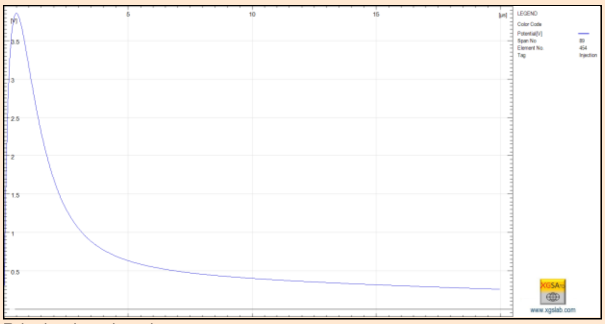
Normalized frequency spectrum – Log – Log plot

MAIN FEATURES

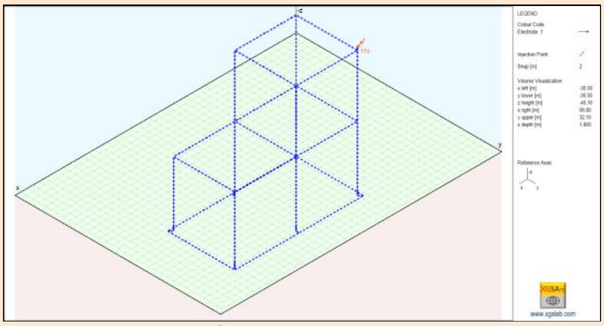
As for XGSA_FD but in the time domain.



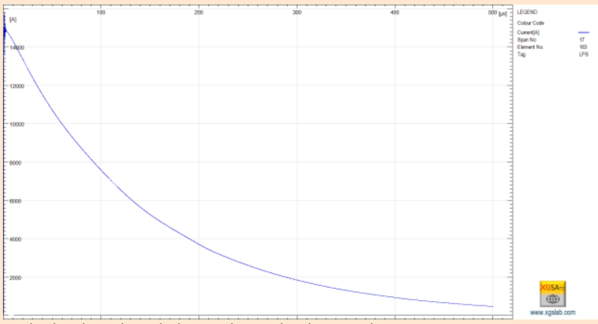
Grid layout with injection point



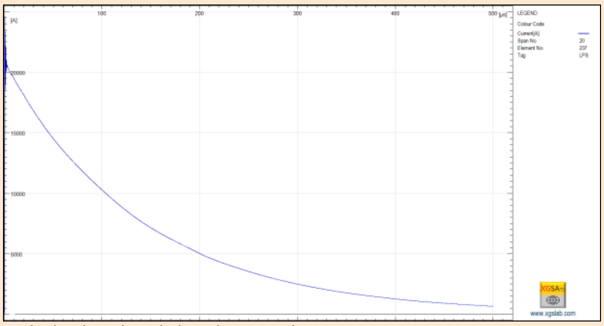
TGPR in the time domain



Lightning stroke in a building LPS



Current in the time domain in an air termination conductor



Current in the time domain in a down conductor

SINT Ingegneria

ONE STEP AHEAD

NETS

NETWORK SOLVER

NETS is a very flexible tool to solve full meshed multi-conductor and multi-phase networks and is based on the multi-phases system representation. NETS can be used to solve networks in steady state or fault conditions. In particular, NETS can be used for the calculation of the fault current distribution in power networks.

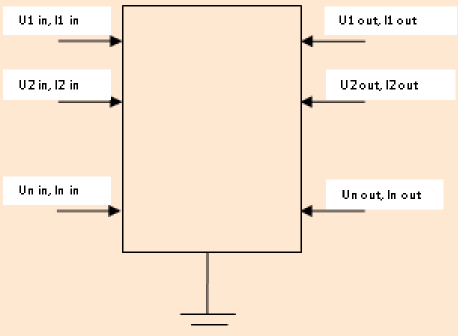
GENERAL DESCRIPTION

NETS is a computation code for the solution of full meshed multi-conductor and multi-phase underground and/or overhead networks in the frequency domain. The application range is limited to the model accuracy of transformers (up to 1 kHz) cables (up to 1 kHz) and lines (up to 10 kHz).

NETS is based on the multi-phase system representation. This approach is general and overcome the classic method of symmetrical components and can be used to represents power systems as multi-conductor networks enabling the consideration of asymmetrical systems also in presence of grounding circuits or circuits with a different number of phases.
The maximum number of conductors (and so of ports for a single cell side) is 26, so enough to represents most network components (the simulation of 6 cables with core, screen and armour requires 18 conductors).
The network components (feeders, ideal voltage generators, ideal current generators, loads, transformers, lines, cables, impedances, switches, faults …) are represented with multi-port cells and the connection between cells is obtained by means of multi-port buses.
NETS calculates parameters of lines and cables starting on data normally available in commercial data sheet.
NETS calculates self and mutual impedances and admittance for all conductors using accurate formulas and taking into account the earth resistivity and permittivity.
NETS calculates parameters of single-phase or three-phase transformers starting on data normally available in commercial data sheet.
NETS can be used to solve symmetrical or asymmetric, balanced or unbalanced transmission and distribution networks in steady state or fault conditions. In particular, NETS can be used for the calculation of the fault current distribution in power networks and so, the actual fault current flowing into a grounding system.
Another typical application of NETS is related to the neutral grounding resistor sizing.

INPUT DATA

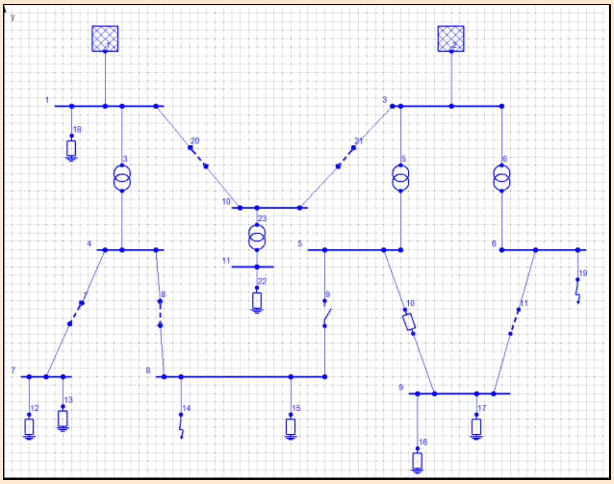
- The input data interface has been designed in order to require a minimum and simple set of information
- Circuit Layout (buses and cells distribution and connection)
- Data for generic cells (e.g. cell class, cell type, ports numbers, and for each port, phase from A to Z and parameters like voltages, currents and impedances)
- Data for line and/or cable cells (as a generic cell and in addition, line or cable length, earth resistivity, operative temperature and, for each port, library code and cross section layout information). Line library and cable library include all additional data required by line and cable cells
- Data for transformer cells (as a generic cell and in addition, library code, neutral impedances, and for each port, longitudinal impedances). Transformer library includes all additional data required by a cell transformer



Multi-port Cell

OUTPUT RESULTS

- Current on each port of each cell
- Current to earth in each connection to earth
- Potential on each port of each cell
- Potential in each connection to earth
- Power flow on each port of each cell
- Results are available in numerical ad graphical form



Network layout

MAIN FEATURES

- Calculation model based on multi-conductor and multi-phase circuit theory
- Automatic debug of data before calculation
- Automatic recognition of the connections between cells and buses
- Arbitrary number of buses and cells (the number is limited only by the hardware constraints)
- Cells class 1: multi-port cells with only a group of ports (input) used to represent feeders, ideal voltages or currents sources, transverse impedances or faults
- Cells class 2: multi-port cells with two group of ports (input and output) used to represent lines, cables, transformers, longitudinal impedances or switches
- Buses: multi-port buses with an arbitrary number of group of ports
- Automatic calculation of cables, lines and transformers parameters
- Cable cells can represent single core or pipe type cables. Each single cable can includes core, screen and armour
- A single cell can represent a long line or a long cable or a single span or part of it. The detail level in the model can be decided by the User
- Transformer cells can represents single-phase or three-phase transformers. Three-phase transformers can have any group number (0 to 11) and any kind of neutral state (insulated, grounded, and generally grounded with an impedance to earth) and neutral distributed or not
- Longitudinal impedance cells can represent interruptions of all or single phases
- Transversal impedances cells can represent any kind of short circuit between phases and/or to earth
- Libraries with commercial data for lines, cables and transformers
- Possibility to choose the language (English, German. French, Italian, Spanish)