

SafeGrid Tutorial

Modelling Wind Turbine Earthing Grid in 3D

The following tutorial is designed to help users of SafeGrid Earthing Software to learn about and practice the application of powerful operating principles.

This tutorial and the contained images were produced using *SafeGrid Version 2.4* however the same principles may be applicable and similar functions available for other older or newer versions also.

Contents

1.	Modelling earth grids using CAD	. 2
1.1	Advantages	2
1.2	Rules	2
2.	Drawing wind turbine earthing grid in 3D	3
3.	Importing 3D DXF File into SafeGrid	. 5
4.	Setting the Fault Location Segment no.	6
5.	Setting surface voltage plot locations	7
6.	SafeGrid results	8



1. Modelling earth grids using CAD

SafeGrid can import grids which were drawn in 2D or 3D using a CAD program which can export files in the DXF file format.

1.1 Advantages

The advantages of importing grids from CAD include:

- a) Earthing design drawings which have been created in CAD can be imported without re-drawing. This saves time and also ensures the model representation of the grid accurate.
- b) Complicated and custom grids which may be difficult to create with the in-built grid editor can be analysed.
- c) Buried conductor arrangements drawn in 3 dimensions (3D) X, Y, Z coordinates system can be modeled.

1.2 Rules

a) Measurement Units of CAD drawing must be set to Inches, Feet, Millimeters, Centimeters or Meters.

An Drawing Units	×
Length <u>I</u> ype: Decimal Precision: 0.0000	Angle Type: Decimal Degrees Precision: 0 Qockwise
Insertion scale Units to scale inserted content: Meters	
Sample Output 1.5,2.0039,0 3<45,0	
Lighting Units for specifying the intensity of lighting: International	
OK Cancel	Direction

- b) Drawn only using straight Line entities.
- c) Corner of grid drawn at co-ordinates X = 0, Y = 0.
- d) Lines snap connected otherwise an undesired current discontinuity will occur.
- e) If drawn in 3D, Positive (+'ve) Z co-ordinate signifies depth. Any Line with a z co-ordinate (start or end point) of either 0 or < 0 will cause an error.



2. Drawing wind turbine earthing grid in 3D

Draw the grid based on the design drawings using CAD software ensuring that the drawing rules stated in Section 1.2 are followed.

Below is a specific although not necessarily typical earthing arrangement for an earthing turbine which was modelled. The design is based on an earthing practice adopted in the U.K. which uses buried metal plates connected by radial (counterpoise) conductors.

The below design was chosen due to its novelty and challenges in modelling. This arrangement will not be the most economical design for all soil types.



The following page shows the CAD model for a wind turbine earthing arrangement. The model includes:

- Reinforcement meshes which is contained within the concrete foundation of the wind turbine. The mesh is connected to the earth grid and thus included in the earthing model to reduce grid impedance as well as step and touch potentials.
- Metal plates buried at the ends of 12 metre long counterpoise conductors. These plates were represented as tightly meshed straight line connected segments and were buried at 2 + metres (Z = 2 m).







3. Importing 3D DXF File into SafeGrid

- a) Under Build Grid go to Load DXF File.
- b) Lines to include can be either All Lines or Lines in Layer. Specify the Layer Name(s) for the latter.
- c) Select **Depth of Lines in DXF File**. This ensures SafeGrid will read also read the Z co-ordinates for the Line start and end points.

All Lines Lines in Layer Layer Name(s) ETHa EXT_E Depth of burial
Layer Name(s) ETHa EXT_E
ETHa EXT_E
-
Depth of burial
Cepth of Lines in DXF File
Specify Depth of Burial
Grid depth of burial (m)
0.5

# SafeGrid Earthing Software V2.4 www.ELEK.com.au File Data Export Help			
Grid XY Preview	Main conductor Connection Vertical rod	Grid Properties No. of parallel conductors (Nx) 10	Design Settings
17.3 16.0- 14.0- 12.0-		No. of parallel conductors (Ny) 10 (1) Compression ratio (x-axis)	Fault Current Distribution (CDIST)
10.0- 10		1 1 Compression ratio (y-axis) 1	So <mark>il Model</mark> (LM-RES)
4.0- 2.0- 0.0 10 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.011.012.013.014.01 x-axis (metres)	5.016.017.018.019.020.021.022.0 23.9	No. segments (desired) 389 👘 Depth top soil layer (m) 5	Build GRID
Build Grid Segments			Safety Criteria (ISAFE)
Grid co-ordinates	Load Grid from	m CAD File	
Point A (m) Point B (m) Point C (m) Point D (m) X 0 X 30	Acceptable dr	om connected straight Line entities only. rawing units: Inches, Feet, Millimeters,	Display Results (MOI-GND)
	Centimeters, Positive Z coc	Meters. rdinate signifies depth of burial.	EXIT
Ready			



4. Setting the Fault Location Segment no.

SafeGrid's advanced algorithms include modelling of the conductor series impedances. Therefore it is important to specify the location (conductor segment) of the grid where the fault current is applied during the simulations. This affects the dissipation of fault current and also the distribution of surface, step and voltages.

For example, the surface voltage profile is very different when the fault current is applied at the end of one of the long counterpoise (radial) conductors compared to when it is applied at the centre of the reinforcement mesh.



a) Set Fault Location Segment No. equal to 200.



5. Setting surface voltage plot locations

- a) Go to Safety Criteria (ISAFE) module.
- b) Under Plot Surface Voltages select **Over area**.
- c) Set Maximum spacing between points (m) equal to 0.2 m.

Determine Safety For		
✓ Touch Voltages	Region Where Safety Criteria is Assessed	Design Setting
✓ Step Voltages	Main conductor Connection	
Safety Criteria Use allowable safety levels as plotting thresholds		Fault Current Distribution (CDIST)
Maximum GPR of Grid (V) 3000 호 Allowable Touch Voltage (V)		Soil Model (LM-RES)
254.2 Allowable Step Voltage (V) 553.2	Fine Fine Fine Fine Fine Fine Fine Fine	Build GRID
Fault Clearing Time (s)	Plot Surface Voltages Profile Preferences	Safety Criter
Insulating Surface Layer Resistivity (Ohm-m)	Other ine (faster) Over area 0.2	(ISAFE)
Insulating Surface Layer Depth (m)	Grid border offsets for voltage profiles	Display Resul (MOI-GND)
Define Safety Standards (Advanced) >>	1 (*) Touch voltages (m)	EXIT



6. SafeGrid results

Refer to the attached sheets for a demonstration of the output results from SafeGrid.

Note that numerous of the application and site specific data has not been set, calculated or discussed. This includes grid energisation (fault current) level, soil resistivity model, grid conductor size or safety criteria standards and limits.

For this example the following basic data was used.

Soil resistivity: Top layer resistivity = 100 Ohm.m Top layer depth = 5 metres Bottom layer resistivity = 30 Ohm.m

Frequency = 50 Hz Phase-to-earth fault current = 500 A

Conductor sizing: Copper (annealed) conductor 70 mm^2 . Based on ultimate fault current of 20 kA for 1 second. SafeGrid Earthing Software complies with IEEE Std 80 and IEC 60479.

Project: SafeGrid Tutorial Scenario: Modelling Wind Turbine Earthing Grid in 3D

Design Inputs

Table 1:	Soil characteristics	s
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Model	Specify soil model parameters
Top layer resistivity (Ohm.m)	100
Top layer depth (m)	1.5
Bottom layer resistivity (Ohm.m)	30

Table 2: Grid energisation

Units	Current (A)
Magnitude	500

Table 3: Grid and rod conductor size

Method	Specify grid conductor radius
Conductor radius (mm)	4.706258

Table 4: Meas	surement units
	Matria

Units	Metric

Table 5:	System
----------	--------

	5
Frequency (Hz)	50

Buried Grid Model

Table 6 [.]	Segments
i able 0.	Segments

No. of segments accounting for intersections only	476	
No. of segments after segmentation (for accuracy)	488	
Fault location (segment no.)	200	
Total length of conductor network (m)	142.402	



Figure 1: Buried grid preview

Safety Criteria (ISAFE) Calculation

Safety standard (body resistance)	IEEE	
Fibrillation current method	50kg - IEEE	
Body resistance curve (IEC)	-	
Conditions (IEC)	-	
Foot resistance calculation method	IEEE80:2000	
Additional series resistance (i.e. shoe or glove) (Ohms)	0	
Fault clearing time (s)	0.5	
System frequency (Hz)	50	
System X/R ratio	20	
Decrement factor	Default	
Decrement factor value	1.061755	

-		-	11	1
I	able	1:	User	Inputs

-

Sub-surface layer resistivity (Ohm.m)	100
Use top layer soil resistivity? (True/False)	TRUE
Surface material resistivity (Ohm.m)	500
Surface layer depth (m)	0.18

Table 8: Results	
Allowable Touch Voltage Limit (V)	254.184869
Allowable Step Voltage Limit (V)	553.217983
Permissible body current (A)	0.164049
Body resistance - 1 hand to both feet (Ohms)	1000
Body resistance - 1 foot to other foot (Ohms)	1000

Method of Images Grounding (MOI-GND) Modelling

Table 9: Results	
Grid Impedance (Ohms)	1.973
Grid Potential Rise, GPR (V)	986.435

Table 10: Summary of Inputs	
Top soil layer resistivity (Ohm.m)	100
Depth top soil layer (m)	1.5
Bottom soil layer resistivity (Ohm.m)	30
Excitation current (A)	500
Faulted segment no.	200
Final no. of segments	488
Conductor radius (m)	0.004706
Conductivity of buried conductor (S/m)	57E+6
Frequency (Hz)	50
Calculation delta	0.001



Figure 2: Surface potentials (V) - 3D view



Figure 3: Surface potentials - Colour map



Figure 4: Surface potentials (V) - X-Y view







Figure 6: Touch potentials (V) - 3D view



Figure 7: Touch potentials - Colour map



Figure 8: Touch potentials (V) - X-Y view



Figure 9: Touch potentials - Colour map



Figure 10: Step potentials (V) - 3D view



Figure 11: Step potentials - Colour map



Figure 12: Step potentials (V) - X-Y view



Figure 13: Step potentials - Colour map