# 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.

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# 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.

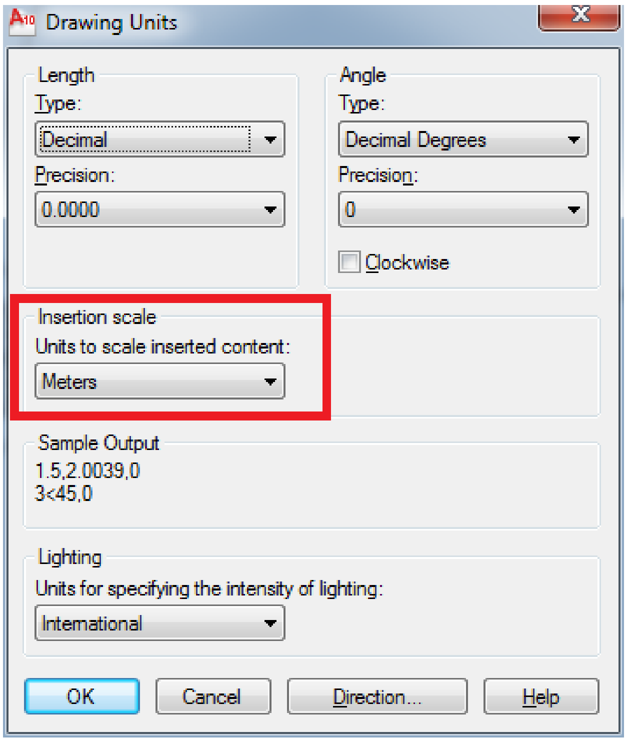
## 1.1 Advantages

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 co-ordinates system can be modeled.

## 1.2 Rules

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



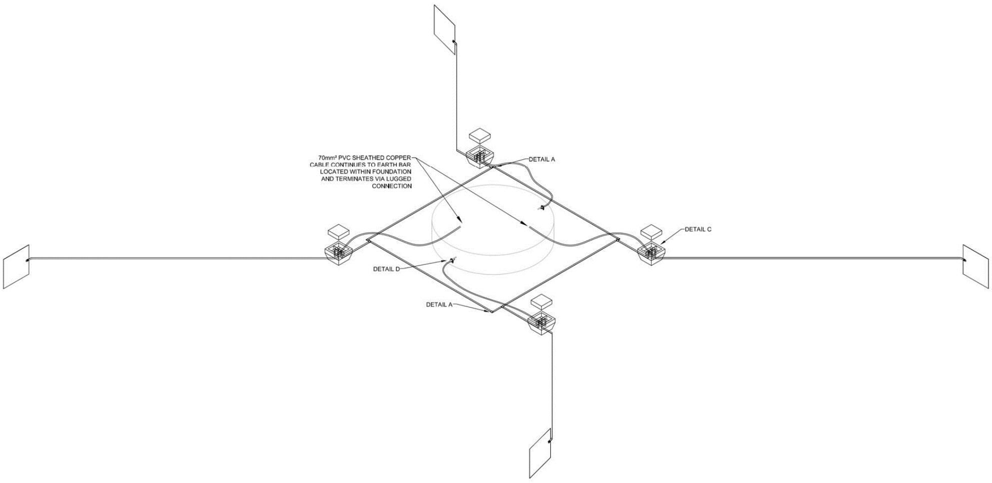

b) Drawn only using straight Line entities.
c) Corner of grid drawn at co-ordinates X = 0, Y = 0.
d) Lines snap connected otherwise an undesired current discontinuity will occur.
e) If drawn in 3D, Positive (+’ve) Z co-ordinate signifies depth. Any Line with a z co-ordinate (start or end point) of either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

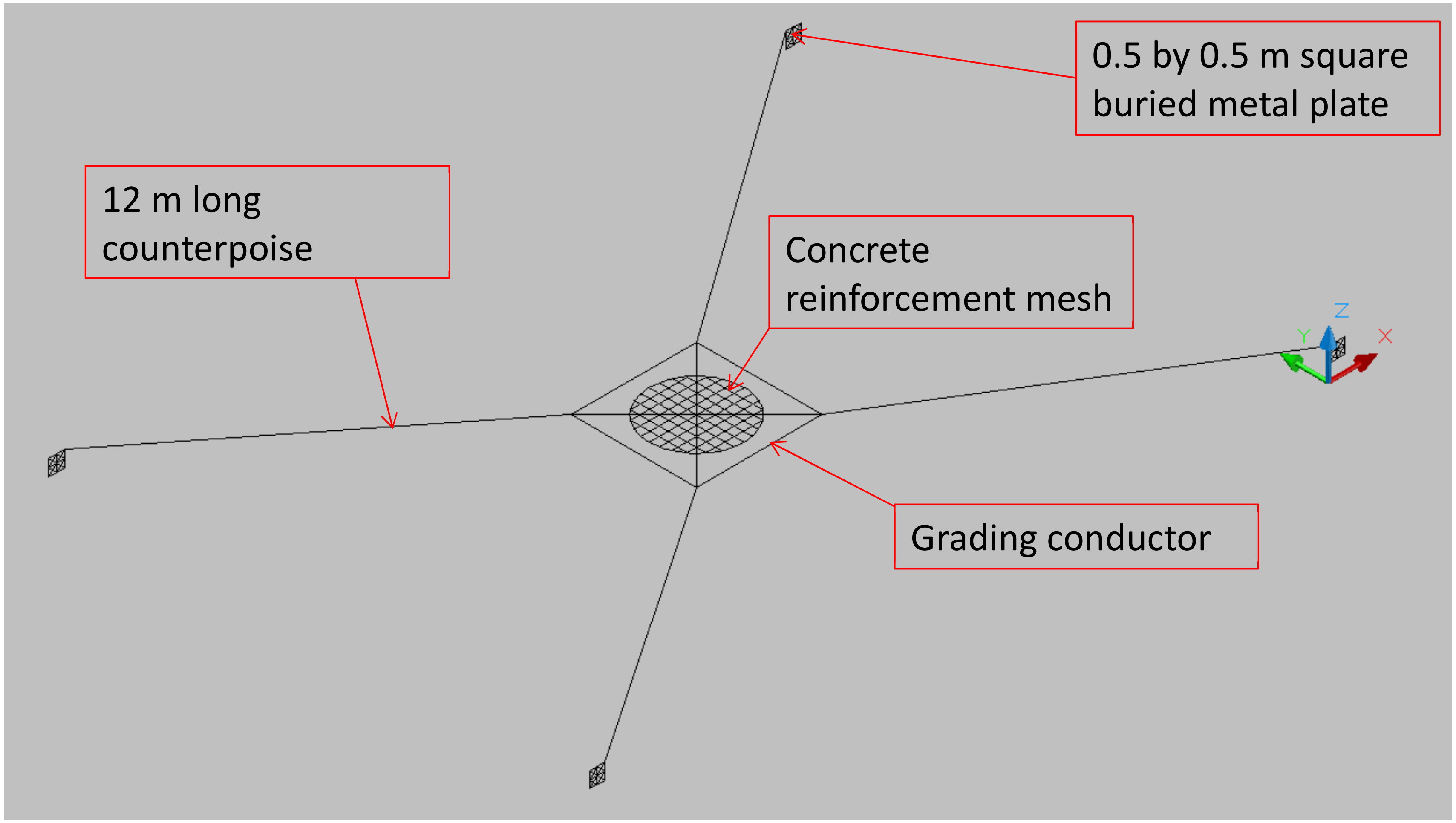
The below design was chosen due to its novelty and challenges in modelling. This arrangement will not be the most economical design for all soil types.




PROPOSED EARTHING ARRANGEMENT
N.T.S@A1

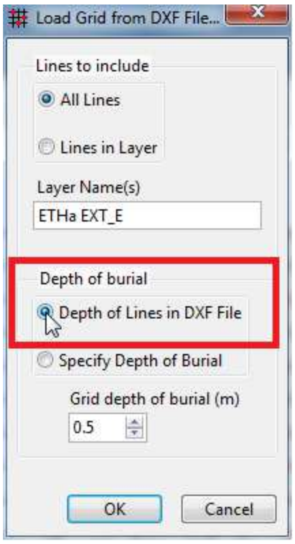
The following page shows the CAD model for a wind turbine earthing arrangement. The model includes:

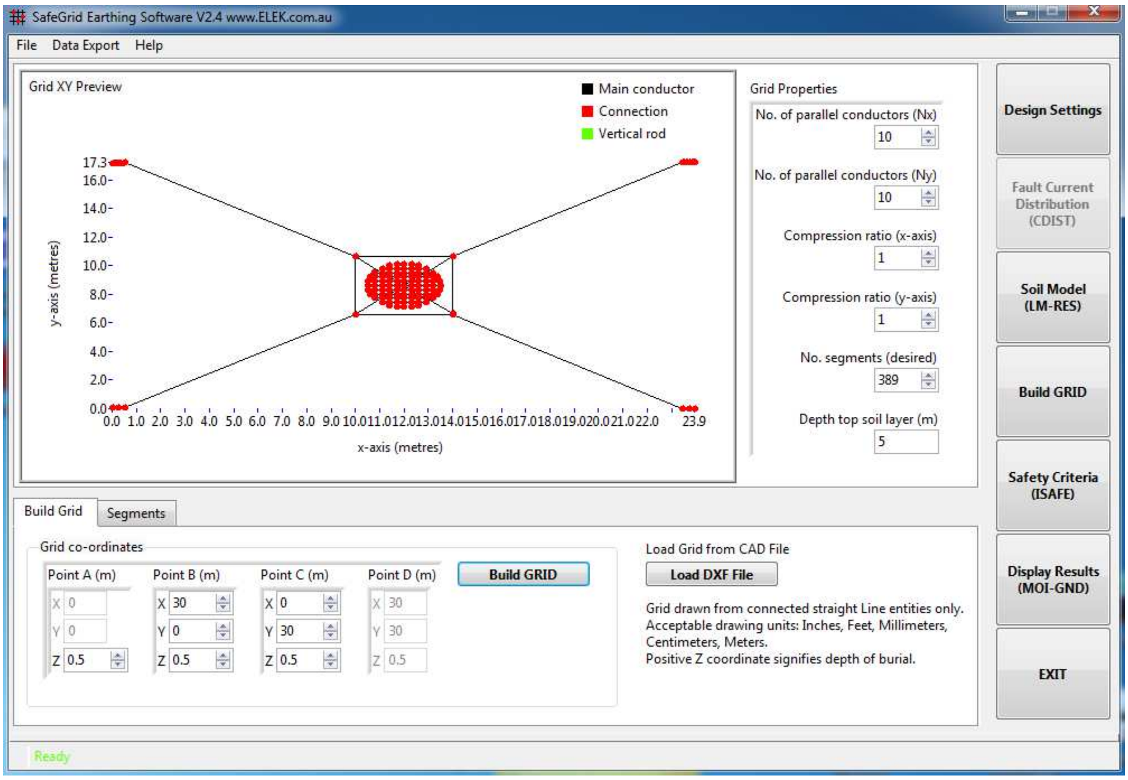
- Reinforcement meshes which is contained within the concrete foundation of the wind turbine. The mesh is connected to the earth grid and thus included in the earthing model to reduce grid impedance as well as step and touch potentials.
- Metal plates buried at the ends of 12 metre long counterpoise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


0.5 by 0.5 m square buried metal plate
12 m long counterpoise
Concrete reinforcement mesh
Grading conductor
Z
Y
X

## 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.



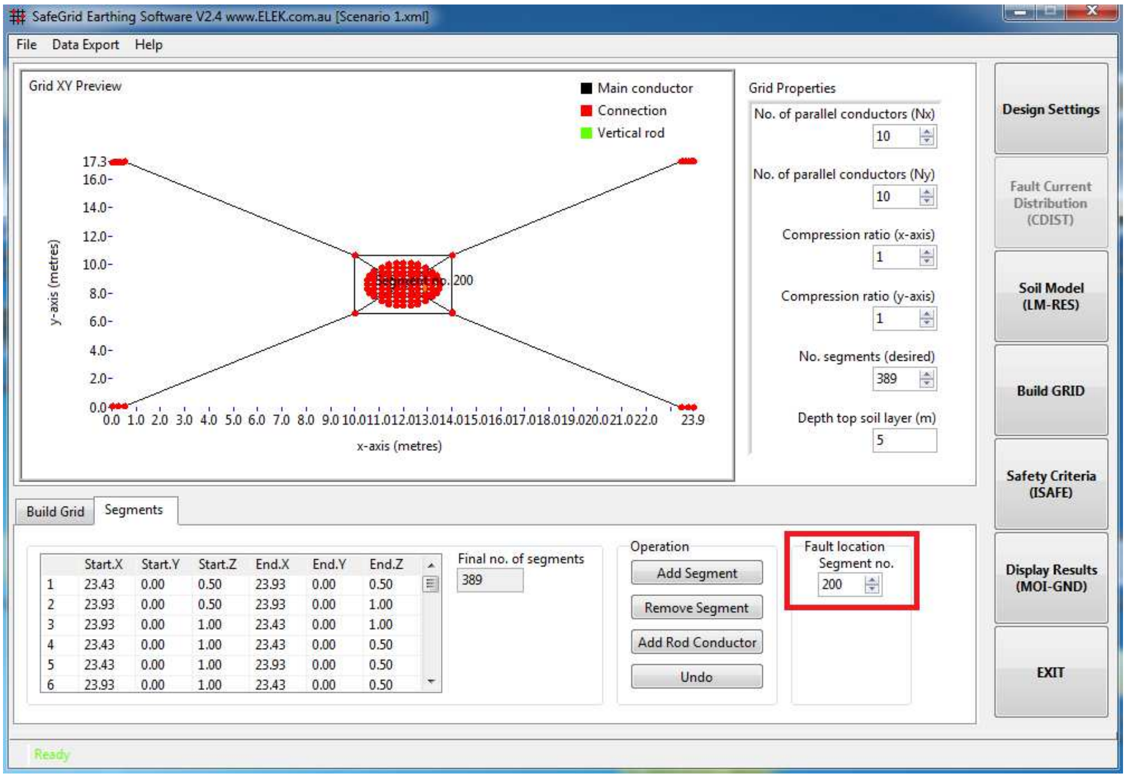



## 4. Setting the Fault Location Segment no.

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.

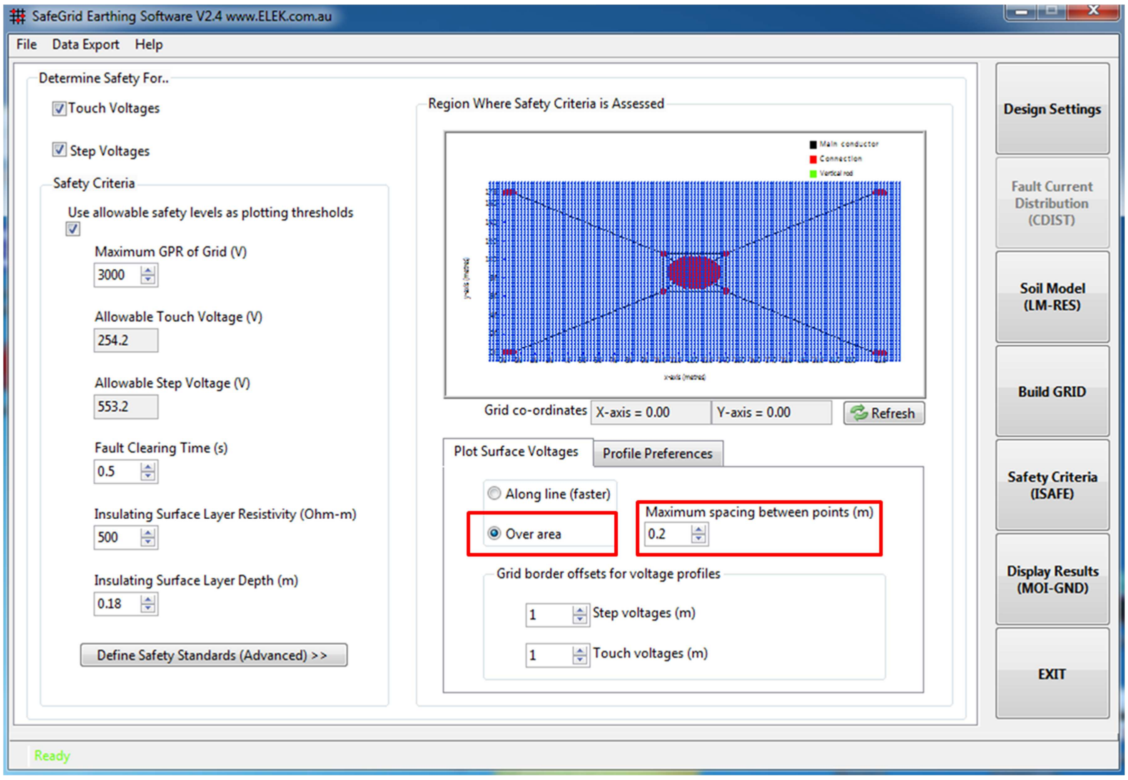
For example, the surface voltage profile is very different when the fault current is applied at the end of one of the long counterpoise (radial) conductors compared to when it is applied at the centre of the reinforcement mesh.

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.



## 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

| | |
|---|---|
| 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: Measurement units

| | |
|---|---|
| Units | Metric |

Table 5: System

| | |
|---|---|
| Frequency (Hz) | 50 |

## Buried Grid Model

Table 6: 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 |

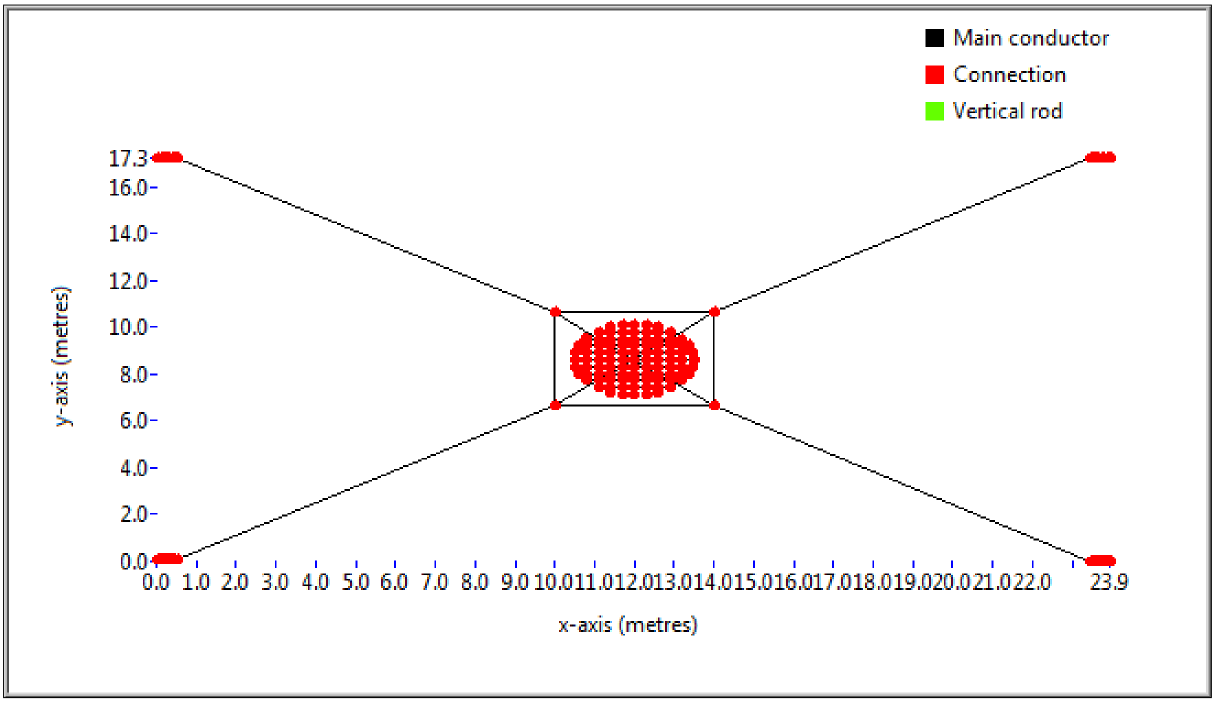



Figure 1: Buried grid preview

## Safety Criteria (ISAFE) Calculation

Table 7: User Inputs

| | |
|---|---|
| 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 |

| | |
|---|---|
| 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 |

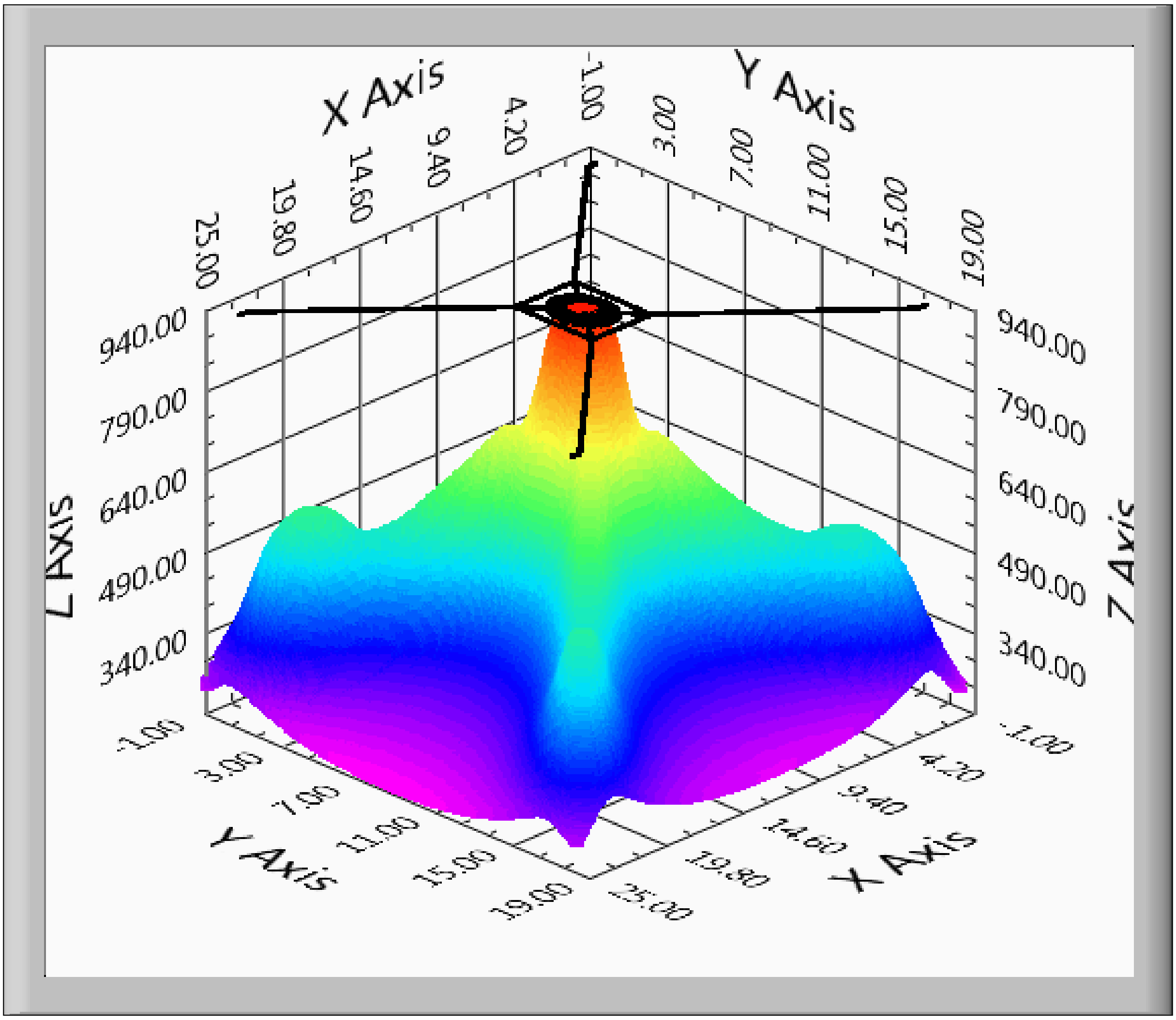



Figure 2: Surface potentials (V) - 3D view

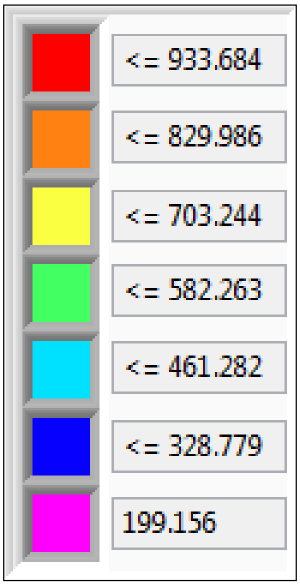



Figure 3: Surface potentials - Colour map

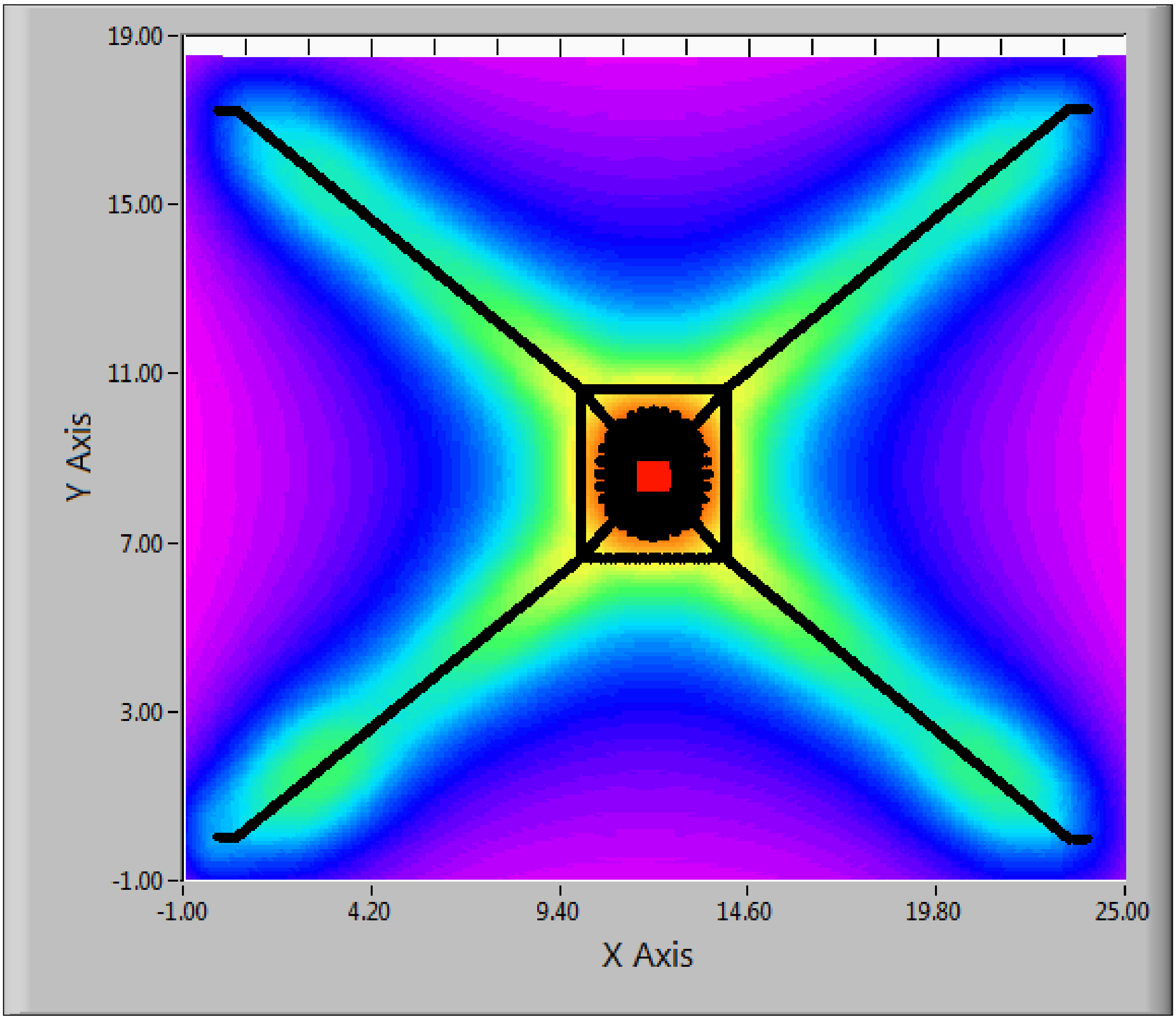



Figure 4: Surface potentials (V) - X-Y view

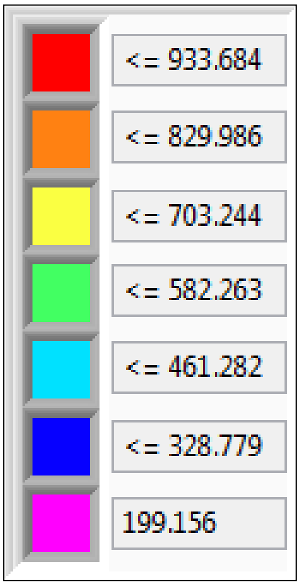



Figure 5: Surface potentials - Colour map

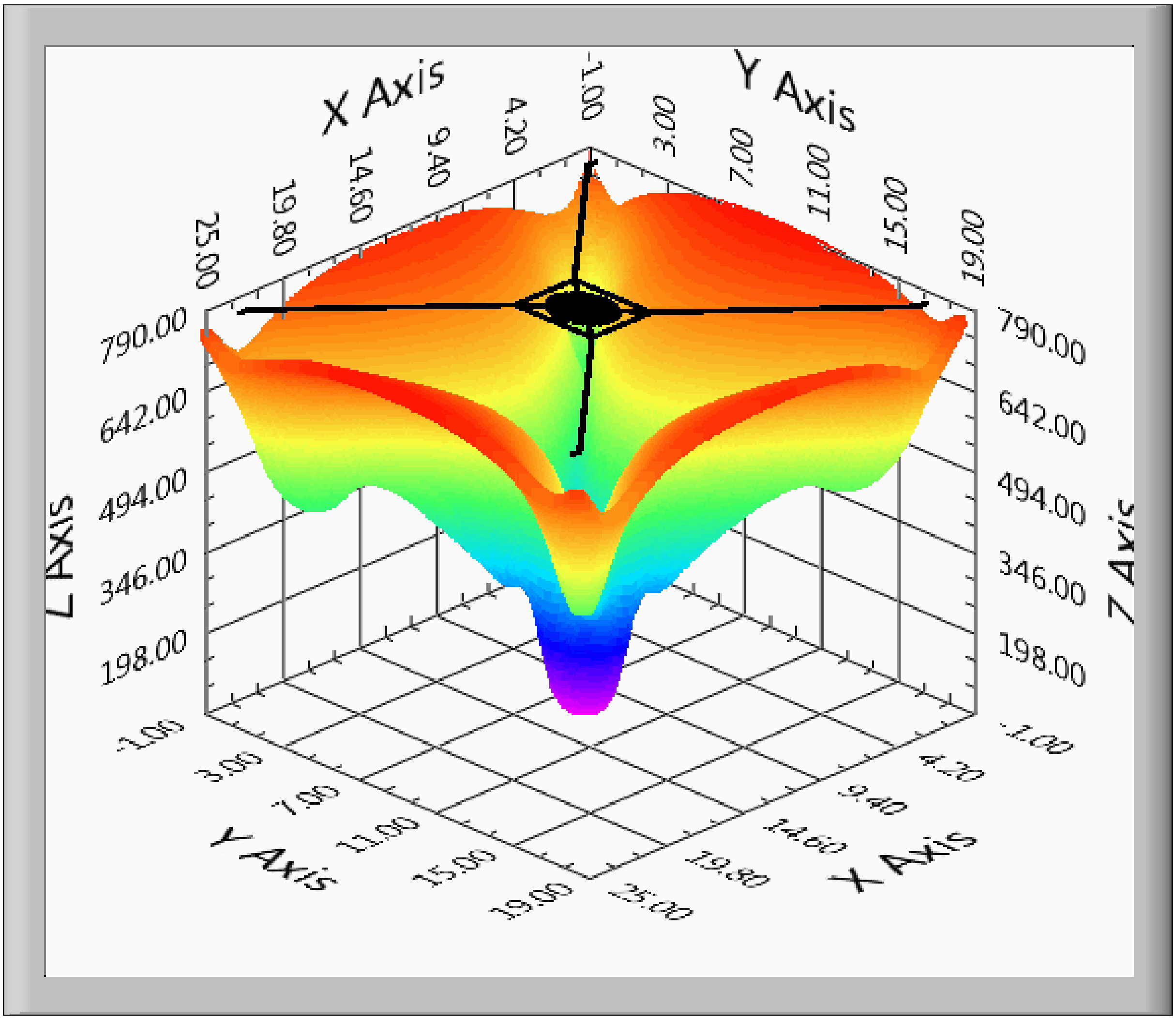



Figure 6: Touch potentials (V) - 3D view

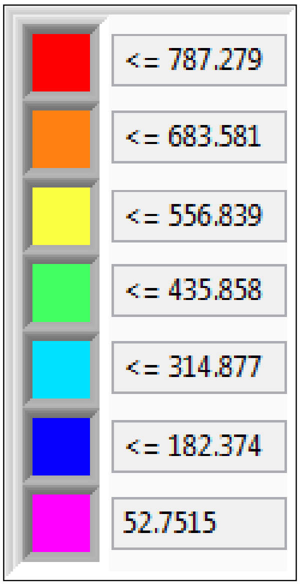



Figure 7: Touch potentials - Colour map

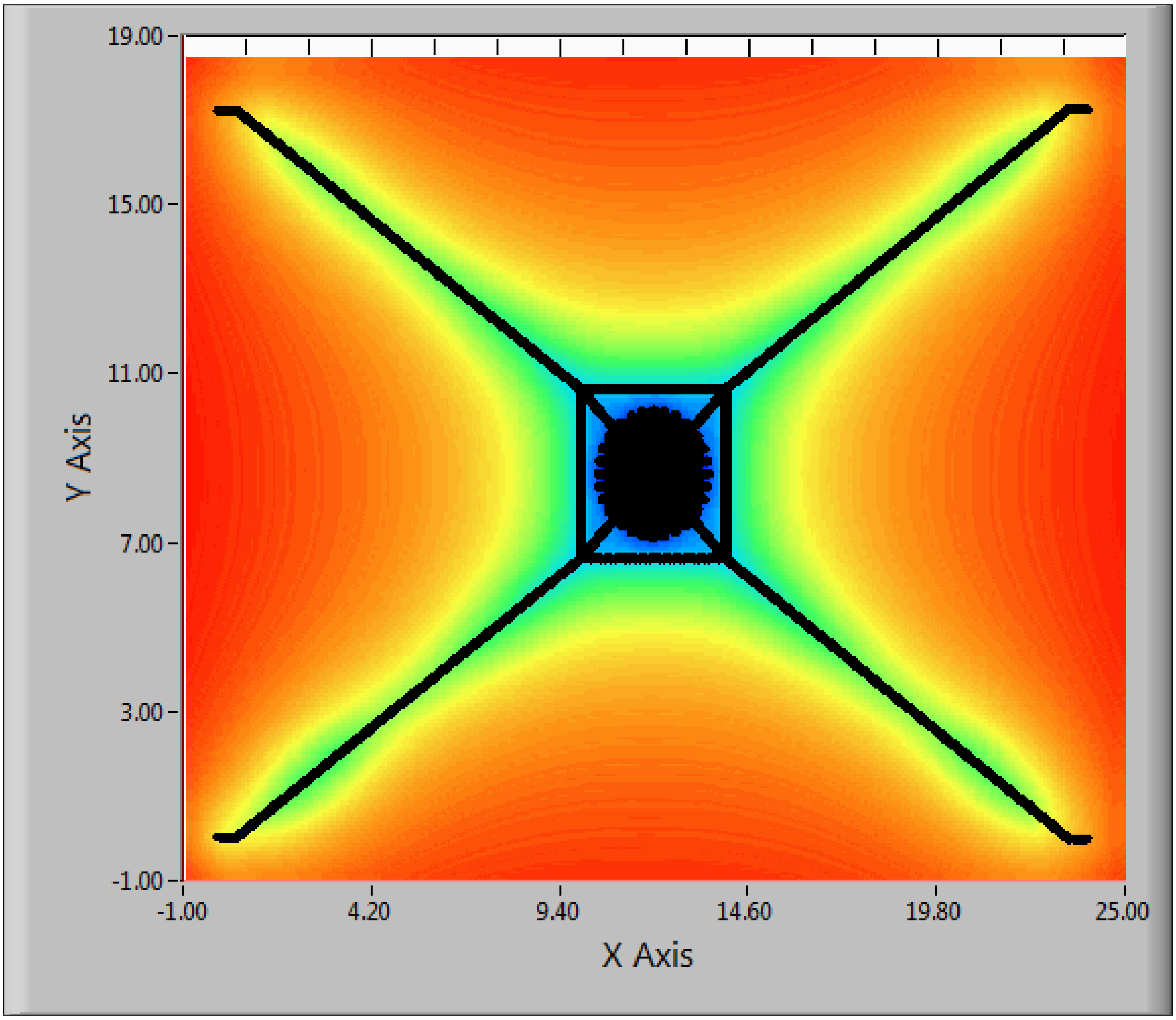



Figure 8: Touch potentials (V) - X-Y view

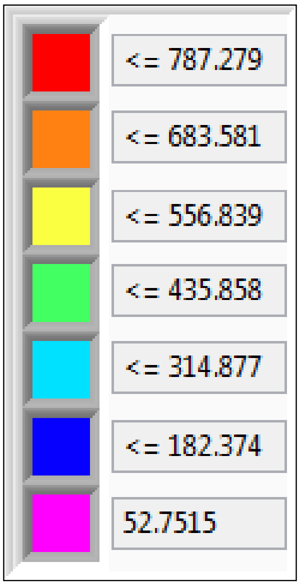



Figure 9: Touch potentials - Colour map

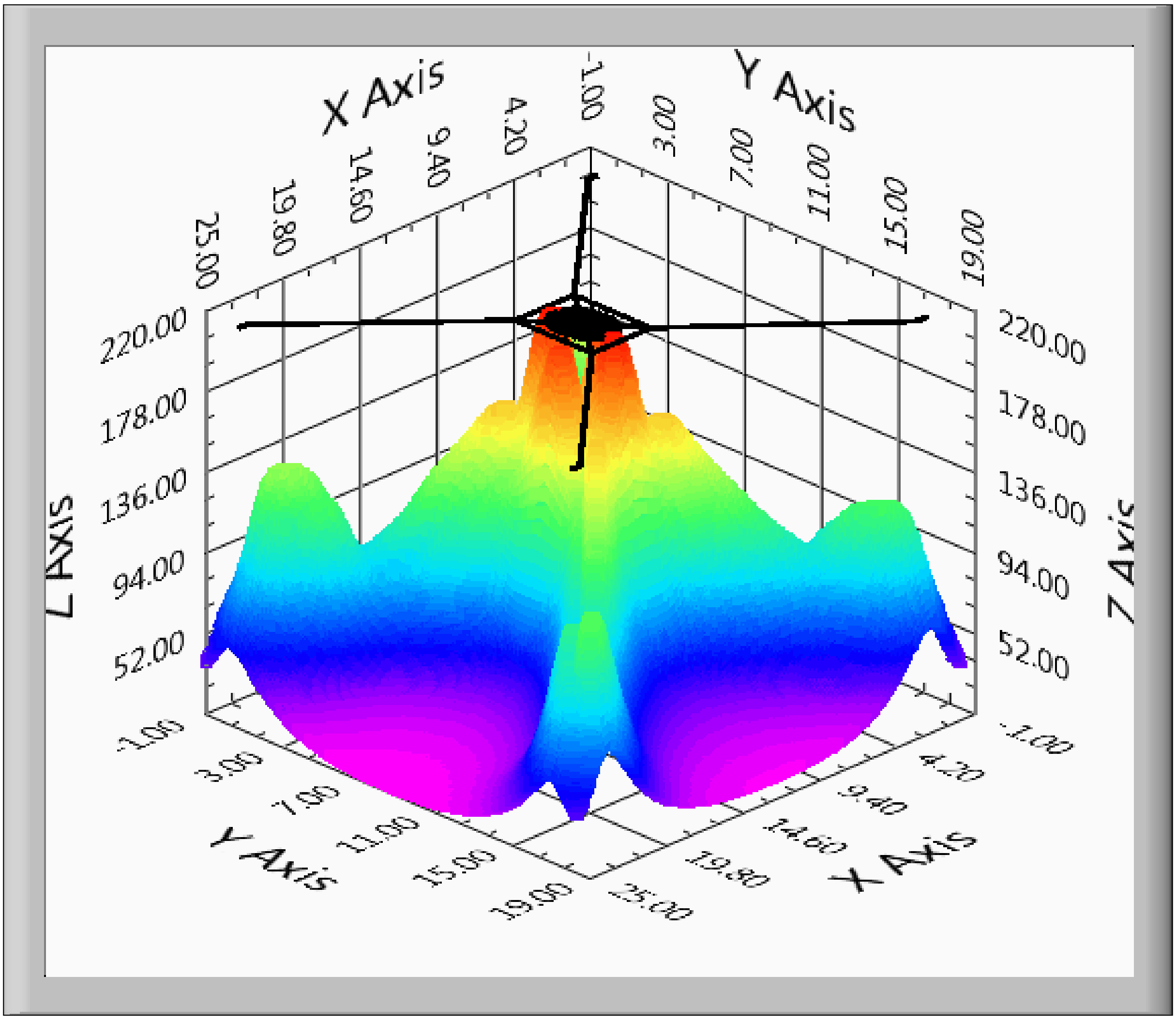



Figure 10:  Step potentials (V) - 3D view

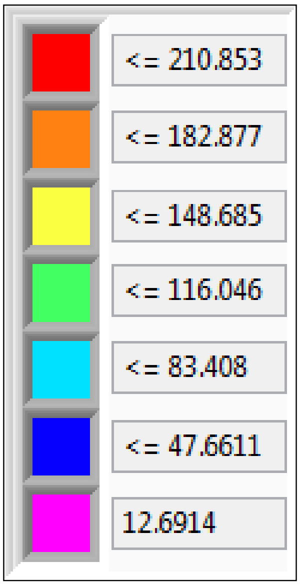



Figure 11:  Step potentials - Colour map

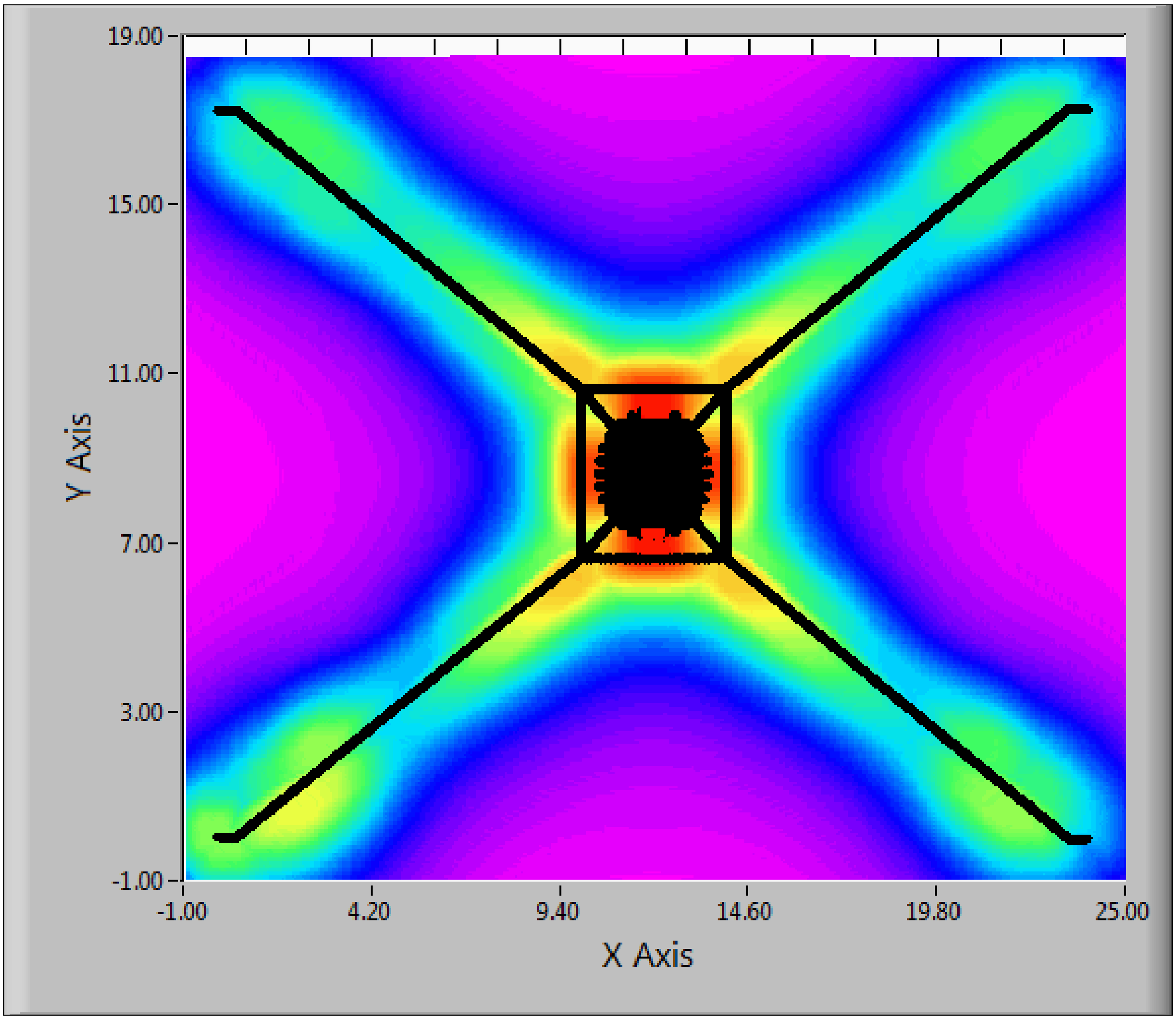



Figure 12: Step potentials (V) - X-Y view

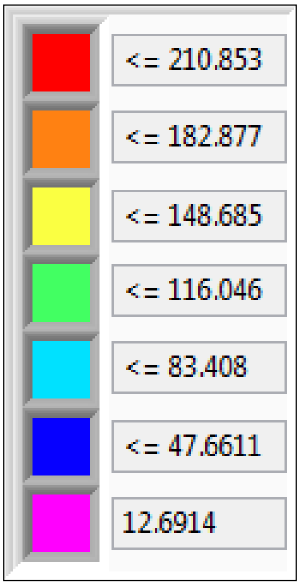



Figure 13: Step potentials - Colour map