SafeGrid Tutorial

Telecomm Mobile Repeater Station – Use of Rods to ensure $R_{grid} \leq 5\ \Omega$

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

This tutorial and the contained images were produced using *SafeGrid Version 2.5* however the same principles may be applicable and similar functions available for other older or newer versions also.

Contents

1. Mobile phone repeater station earthing arrangement

The mobile phone repeater station earthing consists of interconnected grid conductors covering the lease area of 9 m by 14.5 m of conductors buried at a depth of 0.5 m.

The grid is buried at separation distances of 0.5 m and 1 m from the perimeter fence and the shelter building respectively.

There are three 1 m^2 buried plates underneath the concrete pad footing for each leg of the antenna structure.

Rods of 12 m lengths are added as required to reduce the overall earthing resistance.

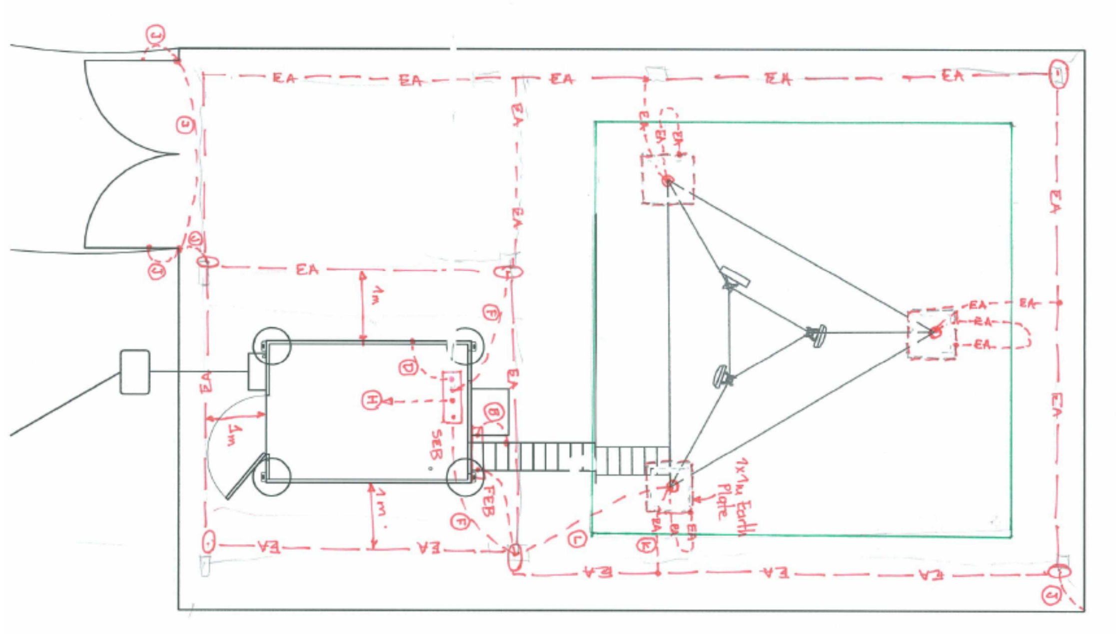


Figure 1 Sketch of mobile phone repeater station earthing system

1.1 Purpose of the earthing system

The purpose of the earthing system is to provide a low impedance path to the earth from personnel and equipment protection during lightning strikes.

The customer has specified that the total earth grid impedance must not exceed 5 Ω.

2. Modelling the earth grid in SafeGrid

The earthing grid was drawn using CAD software and imported into SafeGrid as a DXF file. Figure 2 shows the CAD model for earthing arrangement. The model includes the metal plates which were modelled as tightly meshed straight line connected segments.

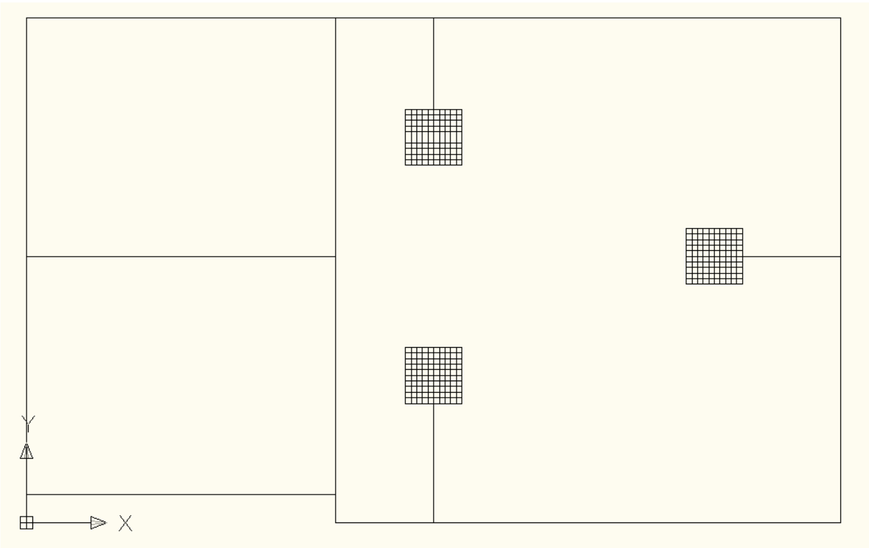


Figure 2 Model of earth grid drawn in CAD and saved as DXF file for importing into SafeGrid

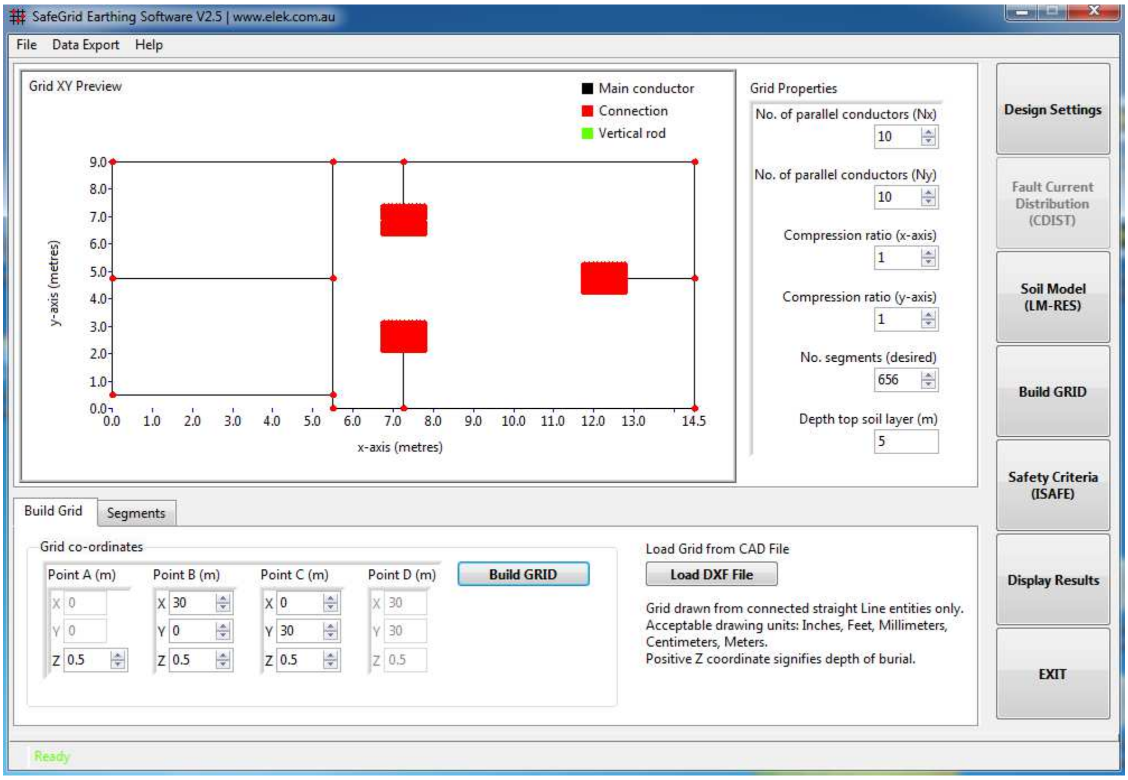


Figure 3 DXF CAD file imported into SafeGrid

3. Soil resistivity modelling

Soil resistivity measurements were taken in the field using the Wenner Array Method at electrode spacing's of between 1 m and 8 m due to space limitations.
Two sets of measurements were taken in different directions. Note it is good practice to take at least 5 measurements per set.

Table 5: Resistivity Test Results

Electrical Spacing 'a' (m)	Resistance, 'R' (Ω)		Apparent Resistivity, ρ=2πaR (Ω.m)	
	E-W Direction	N-S Direction	E-W Direction	N-S Direction
1	900	859	5655	5397
2	521	396	6547	4976
4	122.7	120	3084	3016
8	19.70	21.5	990	1081

Figure 4 Wenner field resistivity measurements

The calculated 2-layer soil model using E-W measurements was as follows (Figure 5):

Top layer resistivity = 6390 Ω-m
Depth of top layer = 3.13 m
Bottom layer resistivity = 139.3 Ω-m
Goodness of fit = 0.928 (very good)

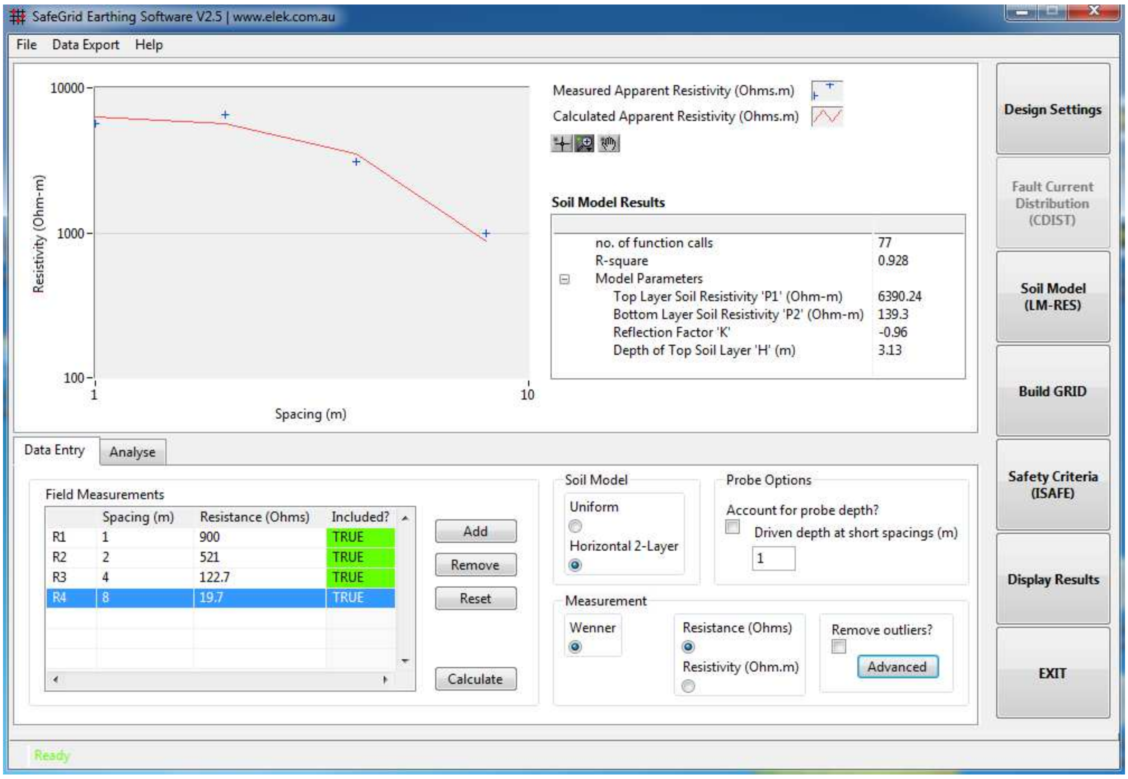
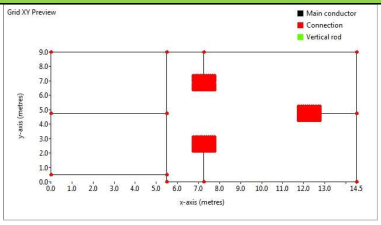
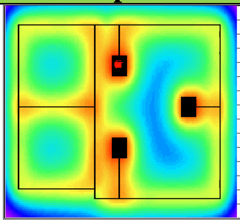
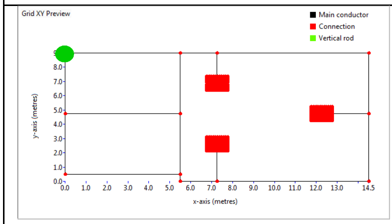
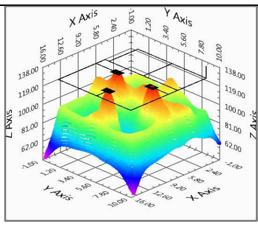
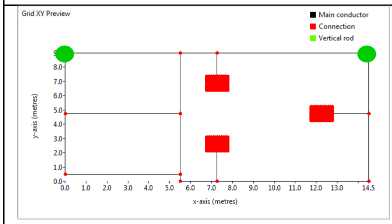
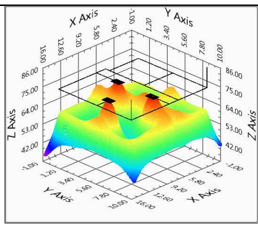
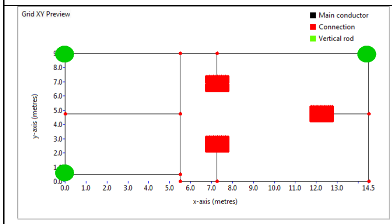
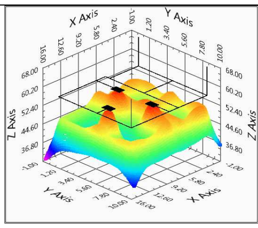
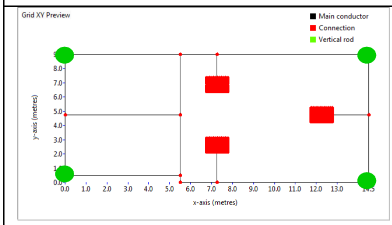
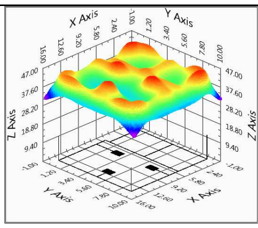
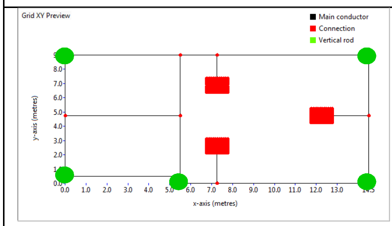
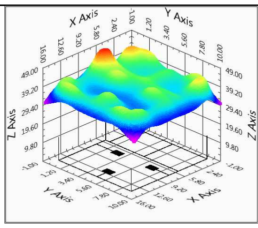


Figure 5 E-W measurements modelled in SafeGrid LM-RES module

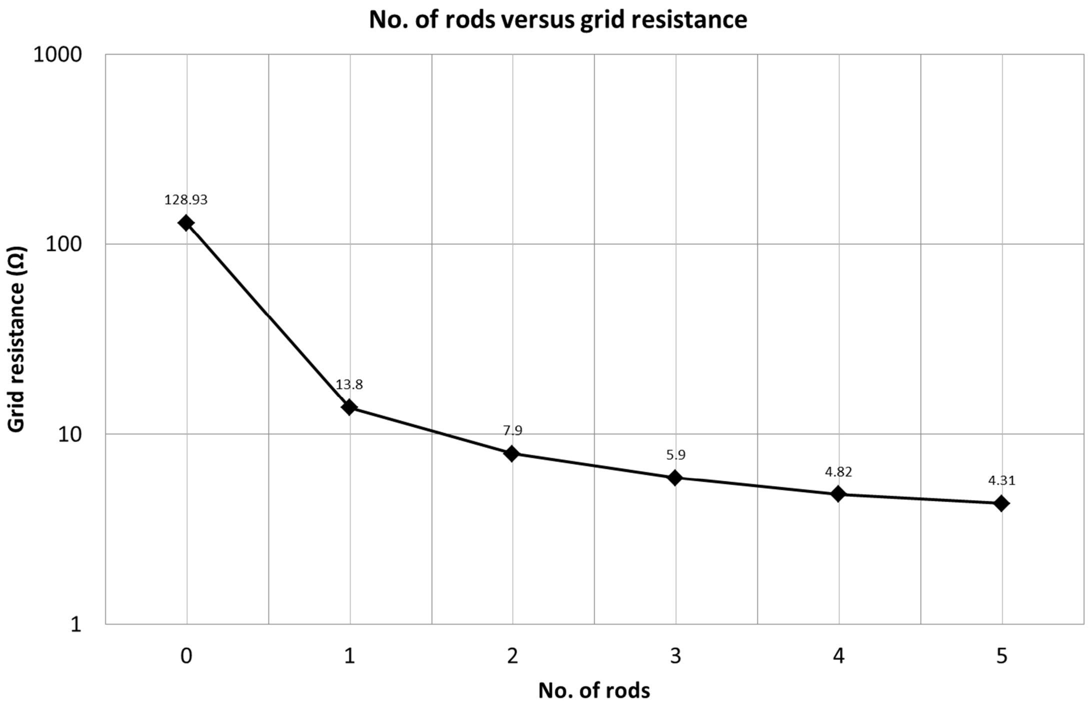
4. SafeGrid Results - calculated grid resistance

Grid resistance was calculated for the various cases as follows:

Grid model	Surface potentials plot	Case	Grid resistance (Ω)
	 XY	**No rods**	**128.93**
	 3D	**1 rod**	**13.8**
	 3D	**2 rods**	**7.9**
	 3D	**3 rods**	**5.9**
	 3D	**4 rods**	**4.82**
	 3D	**5 rods**	**4.31**

4.1 Plot of grid resistance versus no. of rods

Adding rods is very effective at reducing the grid resistance. This is because the rods are penetrating the relatively low resistivity bottom soil layer.



5. Conclusion – No. of rods required

In conclusion adding 4 rods to the grid at the corners is enough to reduce the grid resistance to below 5 Ω.

Appendix - SafeGrid design report for 4 rods case

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

SafeGrid Earthing Software complies with IEEE Std 80 and IEC 60479.

Project:
SafeGrid Tutorial - Telecomm Mobile Repeater Station
Scenario:
4 Rods Case

Design Inputs

Table 1: Soil characteristics

Model	Determine values using soil modelling program (S-RES)
Top layer resistivity (Ohm.m)	6390.243
Top layer depth (m)	3.135
Bottom layer resistivity (Ohm.m)	139.301

Refer to separate page for LM-RES soil modelling.

Table 2: Grid energisation

Units	Current (A)
Magnitude	10

Table 3: Grid and rod conductor size

Method	Specify grid conductor radius
Conductor radius (mm)	10

Table 4: Measurement units

Units	Metric

Table 5: System

Frequency (Hz)	50

Levenberg-Marquardt Soil Resistivity (LM-RES) Modelling

Table 6: User Inputs

Soil model	Horizontal 2-Layer
Measurement method	Wenner
Measurement values	Resistance (Ohms)
Account for probe depth? (True/False)	FALSE
Driven depth at short spacings (m)	-
Remove outliers? (True/False)	FALSE

Table 7: Field measurements

	Spacing (m)	Resistance (Ohms)	Included? (True/False)
R1	1	900	TRUE
R2	2	521	TRUE
R3	4	122.7	TRUE
R4	8	19.7	TRUE

Table 8: Results

Top layer soil resistivity (Ohm.m)	6390.242856
Top layer depth (m)	3.13451
Bottom layer soil resistivity (Ohm.m)	139.30134
Reflection factor, k	-0.957332
Goodness of Fit (R-square)	0.927956

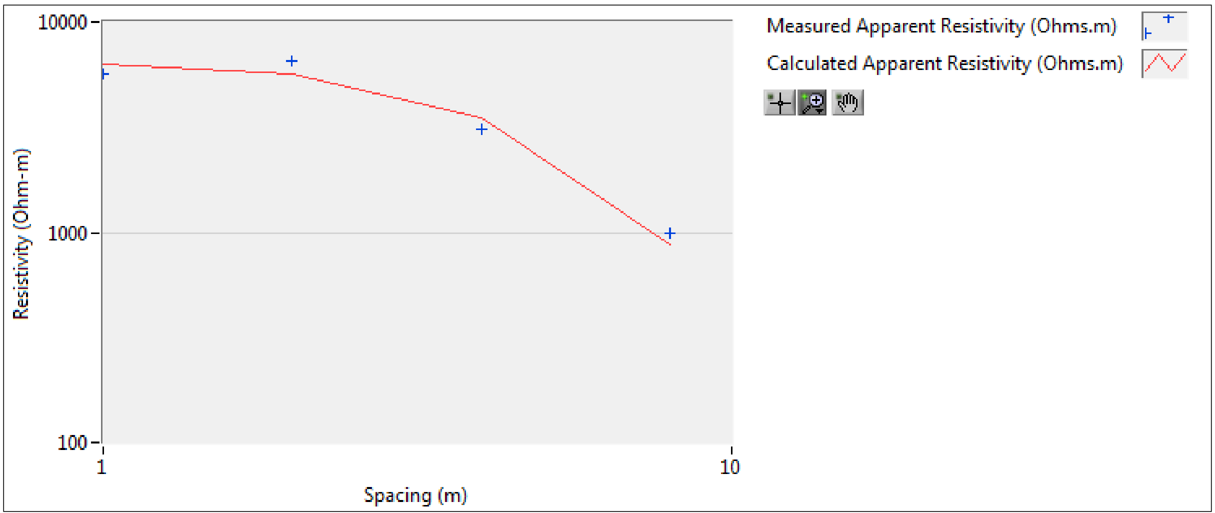


Figure 1: Non-linear model fit to field measurements

Buried Grid Model

Table 9: Segments

No. of segments accounting for intersections only	660
No. of segments after segmentation (for accuracy)	677
Fault location (segment no.)	1
Total length of conductor network (m)	179.5

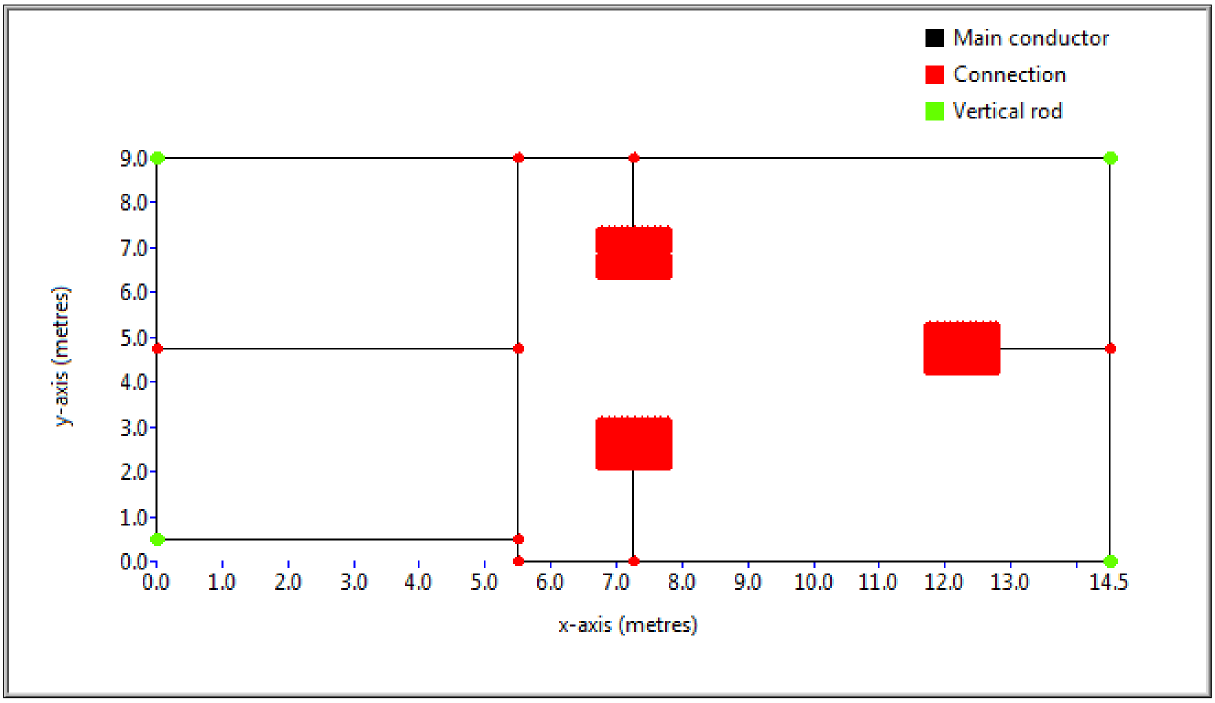


Figure 2: Buried grid preview

Safety Criteria (ISAFE) Calculation

Table 10: 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)	6390.242856
Use top layer soil resistivity? (True/False)	TRUE
Surface material resistivity (Ohm.m)	500
Surface layer depth (m)	0.18

Table 11: 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 12: Results

Grid Impedance (Ohms)	4.825
Grid Potential Rise, GPR (V)	48.246

Table 13: Summary of Inputs

Top soil layer resistivity (Ohm.m)	6390.24
Depth top soil layer (m)	3.13
Bottom soil layer resistivity (Ohm.m)	139.3
Excitation current (A)	10
Faulted segment no.	1
Final no. of segments	677
Conductor radius (m)	0.01
Conductivity of buried conductor (S/m)	57E+6
Frequency (Hz)	50
Calculation delta	0.001

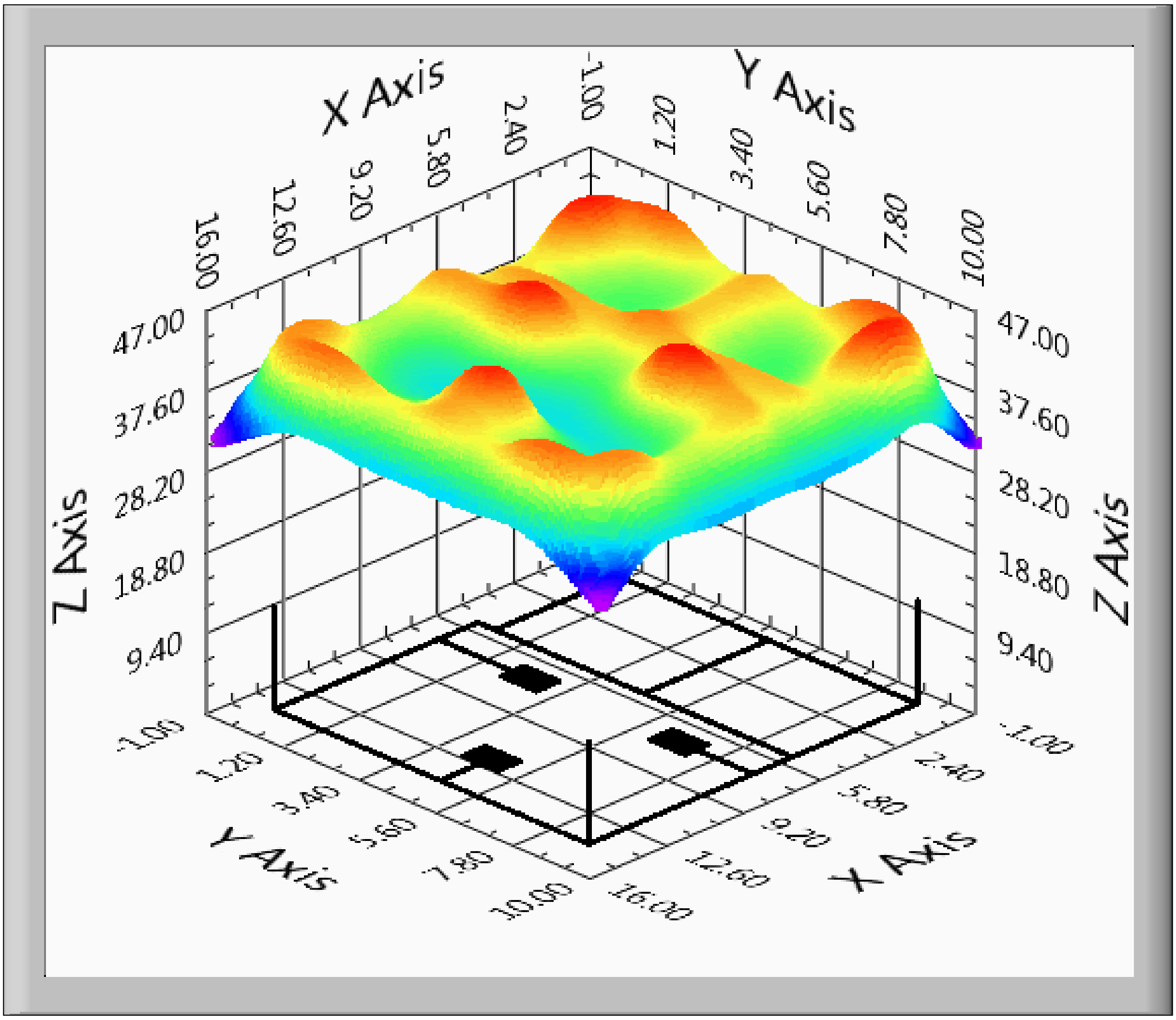


Figure 3: Surface potentials (V) - 3D view

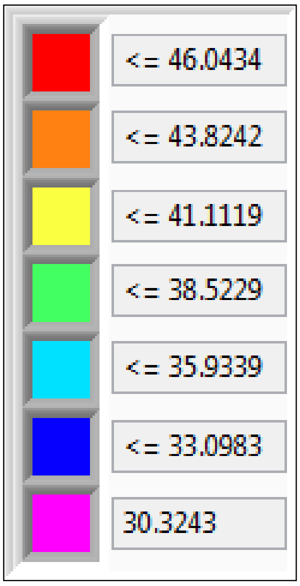


Figure 4: Surface potentials - Colour map

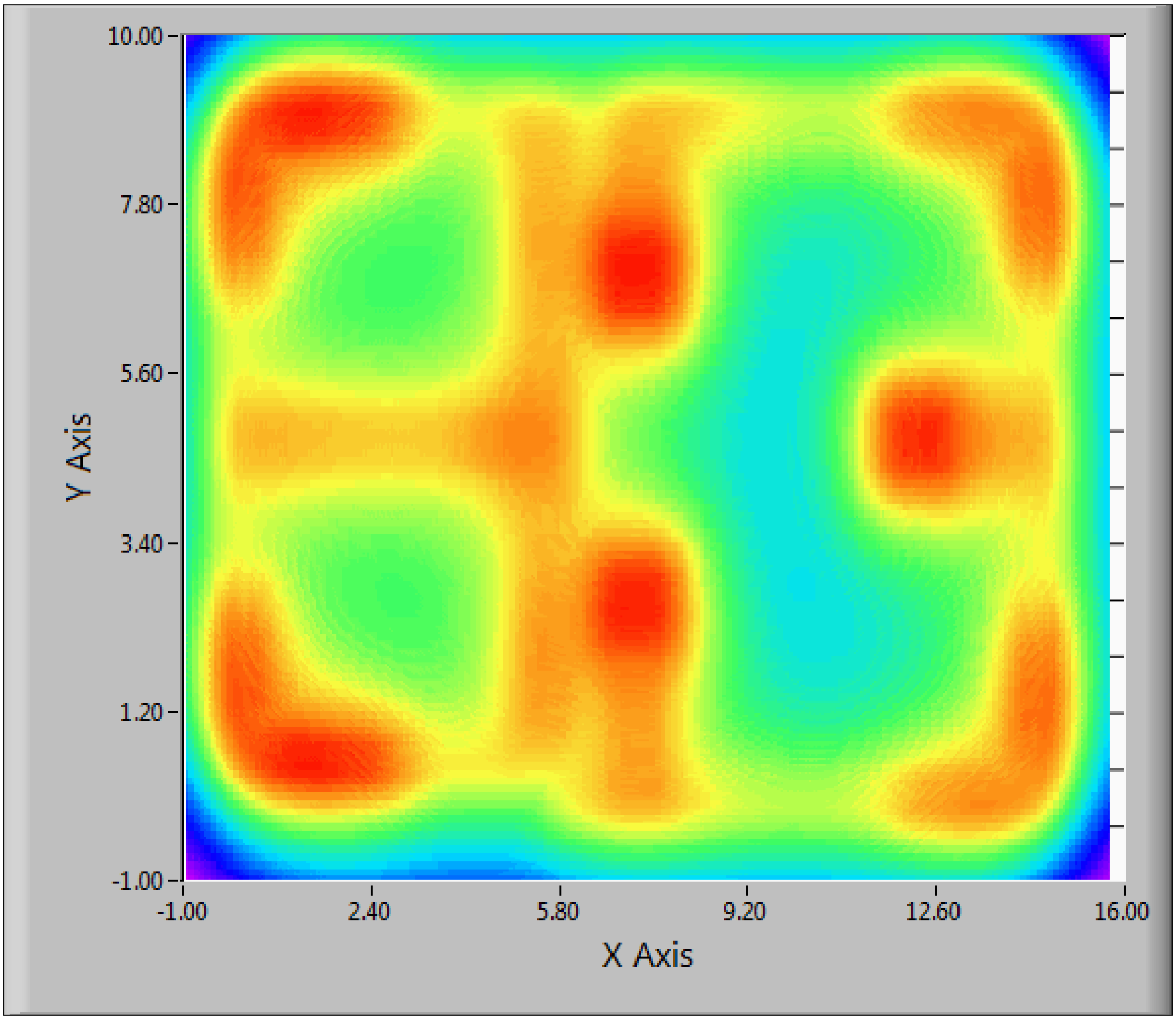


Figure 5: Surface potentials (V) - X-Y view

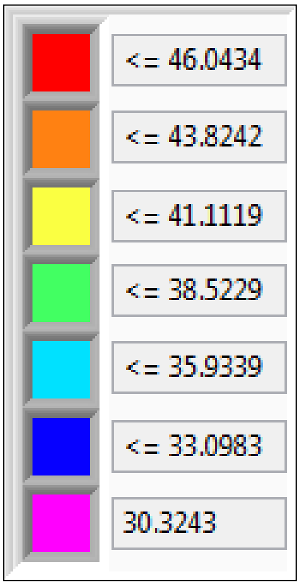


Figure 6: Surface potentials - Colour map

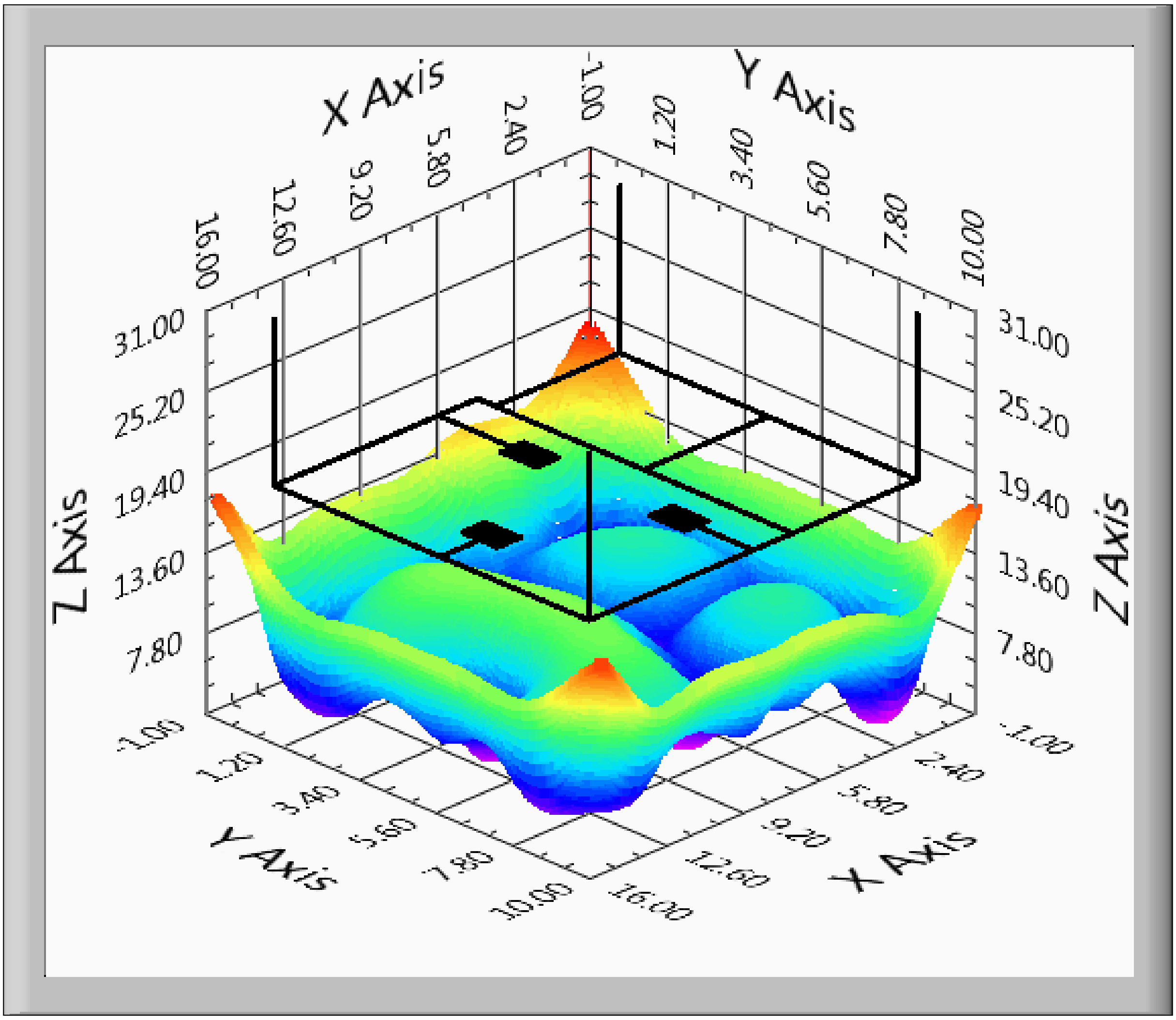


Figure 7: Touch potentials (V) - 3D view

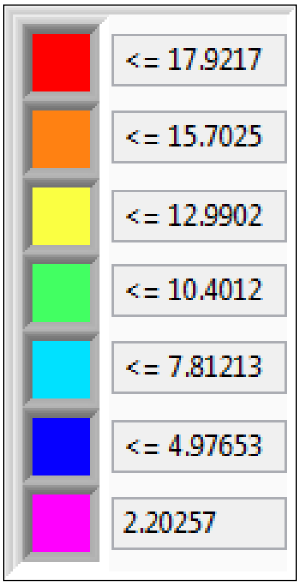


Figure 8: Touch potentials - Colour map

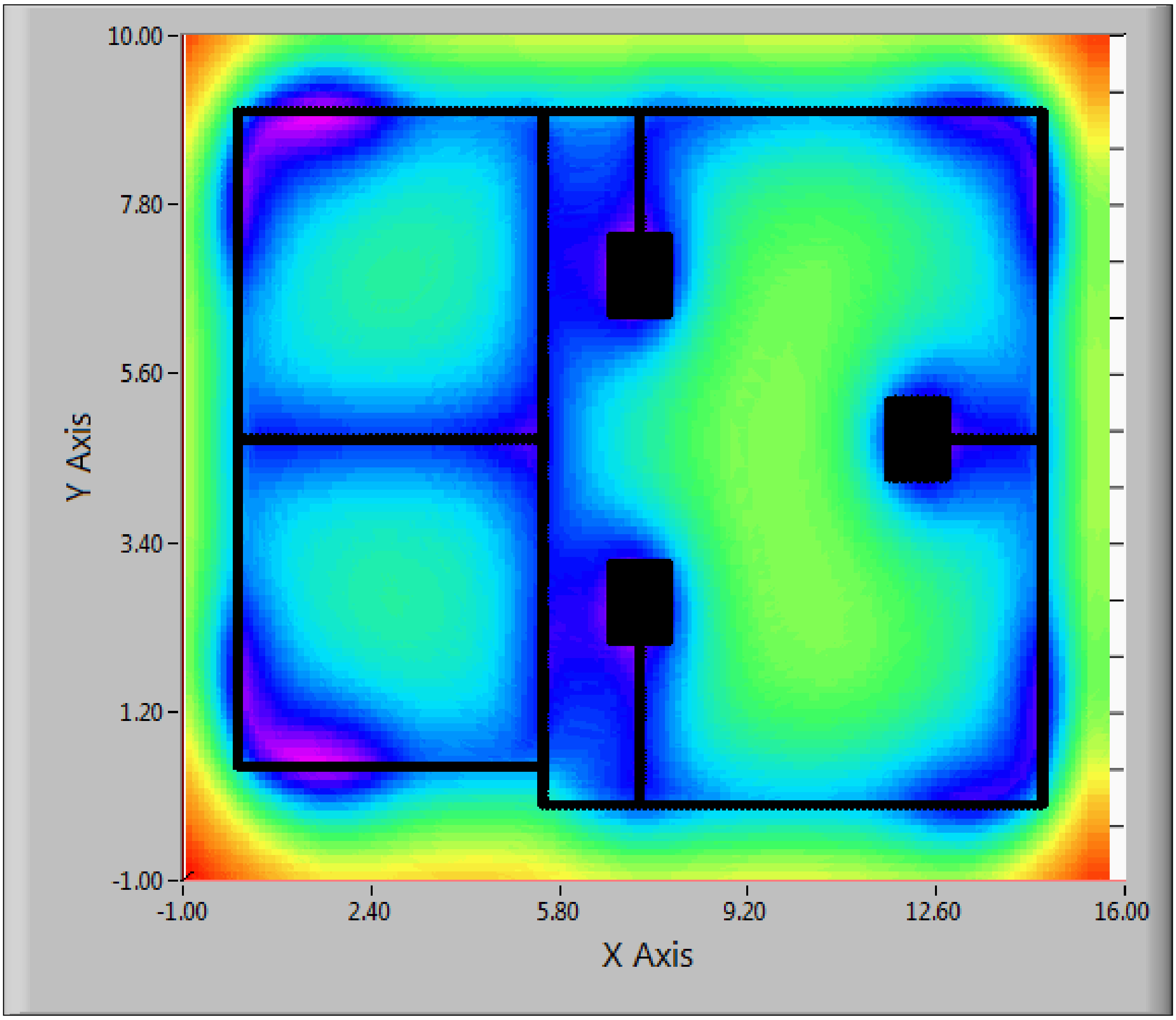


Figure 9: Touch potentials (V) - X-Y view

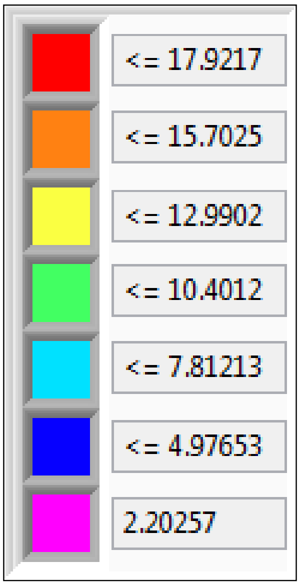


Figure 10: Touch potentials - Colour map

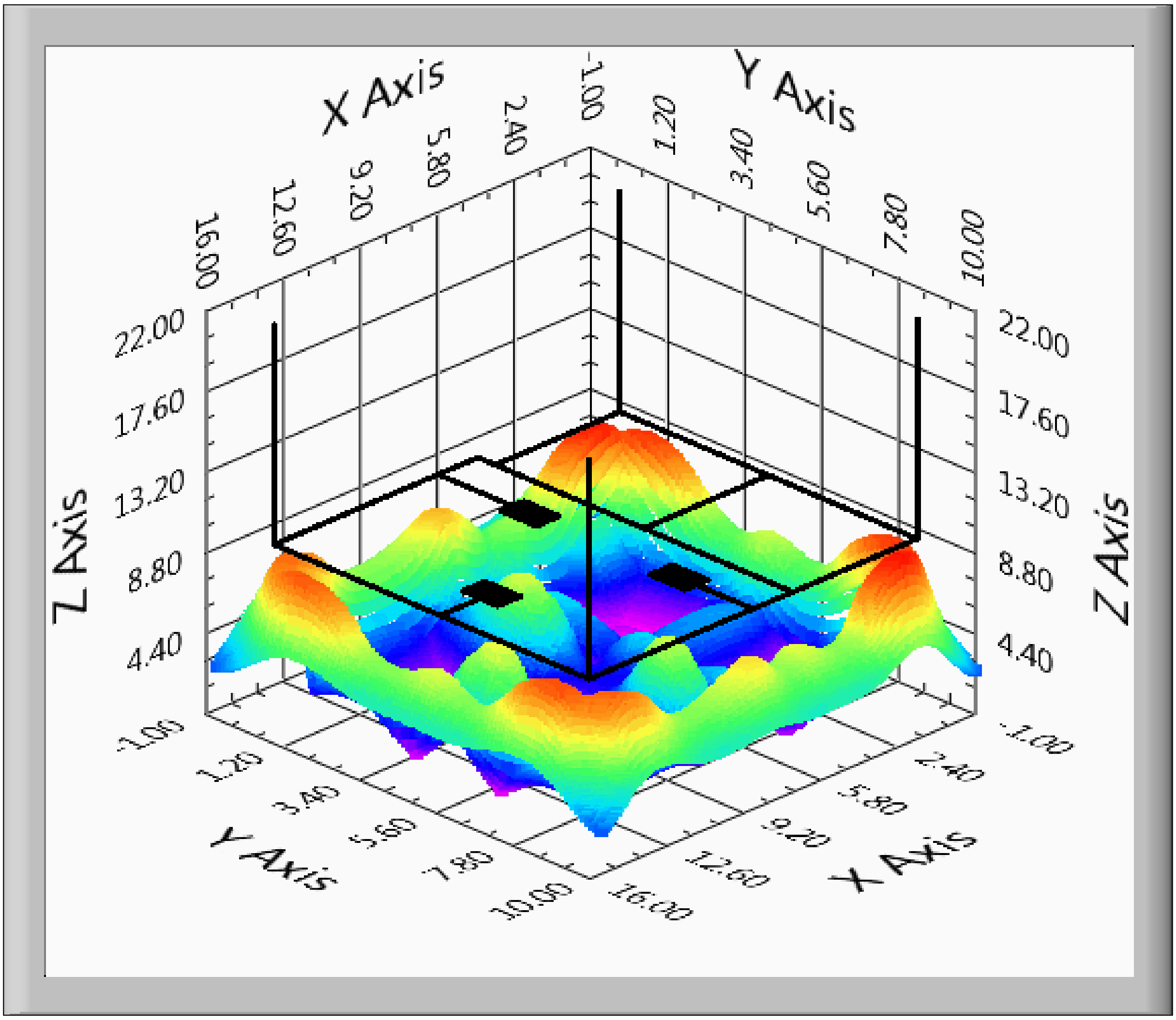


Figure 11: Step potentials (V) - 3D view

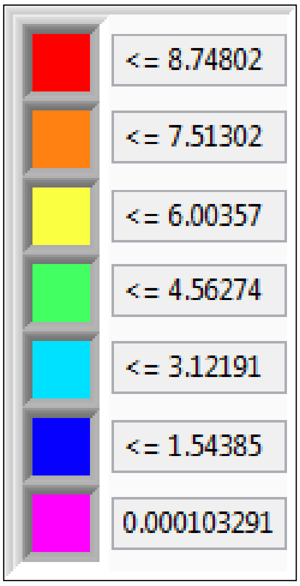


Figure 12: Step potentials - Colour map

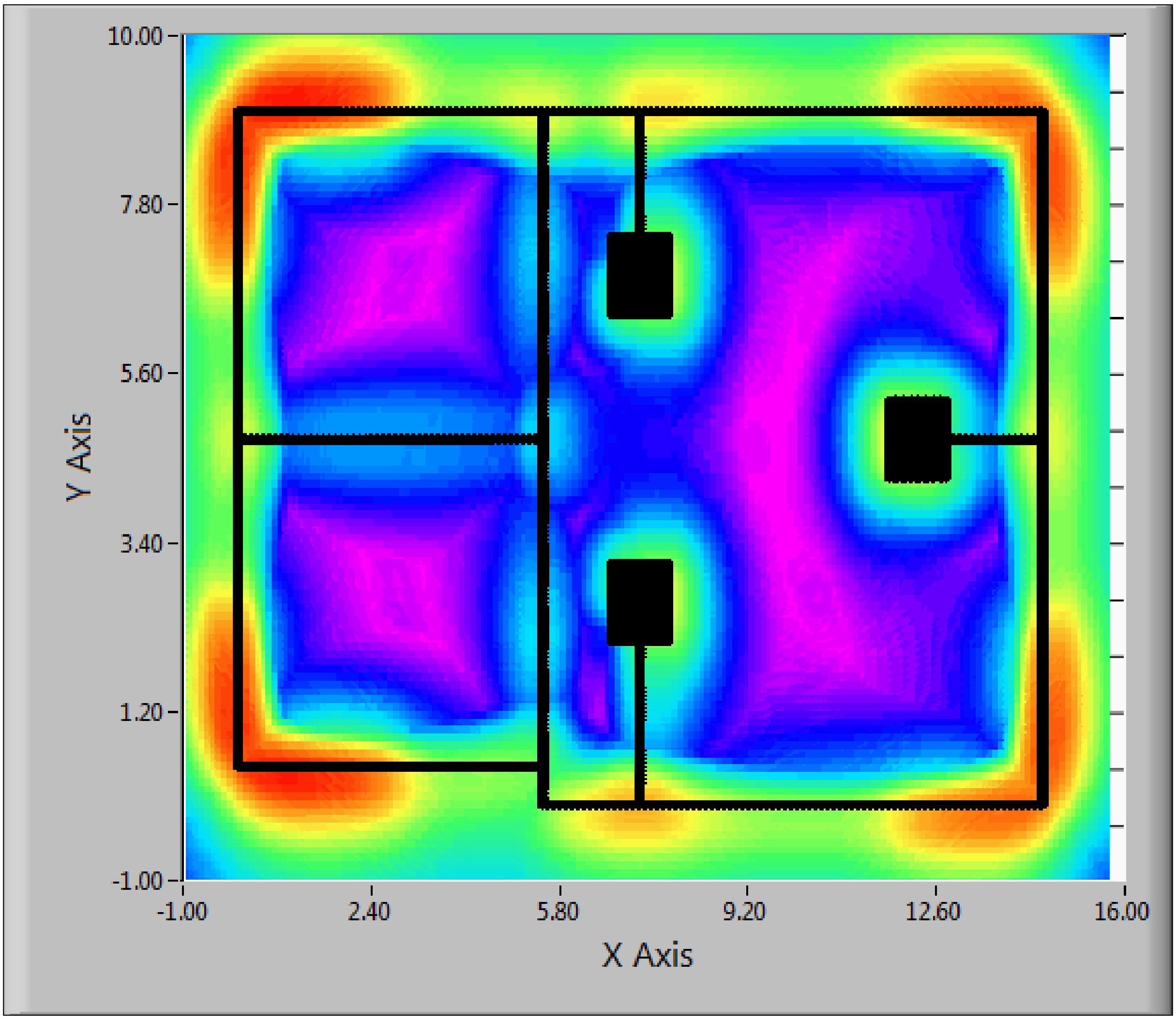


Figure 13: Step potentials (V) - X-Y view

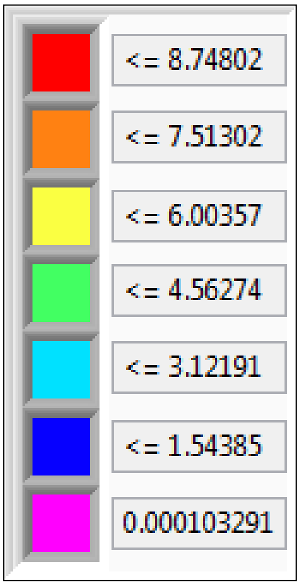


Figure 14: Step potentials - Colour map