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Engineering, Procurement & Construction of High Voltage Power Systems

SUNCREST SUBSTATION
SAN DIEGO GAS & ELECTRIC CO.

BETA PROJECT NO. B537

GROUND GRID DESIGN

BETA DOCUMENT NO. B537-GD
REVISION 3
OCTOBER 21, 2011

10/21/11

Designed by: JHS	Checked by: RMV	Approved by: JAW

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B537
Suncrest Substation
San Diego Gas & Electric Company

The attached ground grid design was obtained using CDEGS 13.3.0.60 from Safe Engineering Services and Technologies Ltd. The design is in compliance with IEEE Std. 80.

Grid Metrics

Clearing Time:	0.5 seconds
Total Fault Current:	40 kA
Soil Resistivity:	See Table 1 (Page 4)
Surface Material:	12" of 3000 Ohm-meter crushed rock
Ground Rods:	433 (0.75" x 120.0")
Mesh Spacing:	Approximately 50'
Grid Size:	Approximately 953' x 1697' at a depth of 12.0"

Design Results

The information included in this Ground Grid Report is the result of calculations performed by the Current Distribution, Electromagnetic Fields, Grounding and Soil Structure Analysis (CDEGS) grounding software. The two modules in CDEGS that were used to analyze and calculate the ground grid design were Soil Resistivity Analysis (RESAP) and Frequency Domain Grounding / Earthing (MALZ).

The CDEGS-RESAP module was used to analyze the soil resistivity data and to model a multi-layer configuration of the soil while the CDEGS-MALZ module was used to analyze the ground grid.

Based on soil results calculated in RESAP, and by using a fault contribution of 40,000 Amps, MALZ calculated the grid resistance to remote earth to equal 0.06966908 Ohms with a GPR of 2786.763 Volts. This data is detailed in the attached Grounding Summary.

The size and type of conductor used for the ground grid is 4/0 AWG stranded copper and 500 MCM stranded copper. Both the 4/0 and the 500 MCM conductors are capable of carrying all of the fault current for a 3 phase fault with a temperature rise not exceeding 1083 °C (fusing temperature) for at least 0.5 seconds. This data is detailed in the attached Ampacity Reports.

A 12" layer of 3000 ohm-meters crushed rock is used as a top-fill material within the substation area. Below the top-fill layer is a 12" layer of earth. The ground grid is placed below the 12" layer of earth. This rock layer allows for all touch voltages and step voltages occurring anywhere in the substation to fall within acceptable limits. This data is detailed in the attached Safety Report.

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Substation Ground Grid Touch and Step Calculations

The ground grid is expected to produce a maximum mesh potential rise in the center of each of the corner meshes, which is less than the acceptable touch voltage limit. Also, the expected step voltage is less than the acceptable step voltage limit. All plots attached at the end of this report confirm that all expected touch voltages within the substation are less than the maximum allowable 804.9 Volts. In addition, all step voltages within the aforementioned area are less than the maximum allowable 2751.5 Volts.

Acceptable Touch Voltage Limit = 804.9 Volts (for a 0.5 second clearing time)
Acceptable Step Voltage Limit = 2751.5 Volts (for a 0.5 second clearing time)

Soil Resistivity Summary

Three soil traverses were taken at the Suncrest Substation. After modeling each of the three traverses in RESAP, it was determined that the resistivity modeled by traverse 1 would be used to perform the calculations for the ground grid design.

Uniform Pin Spacing	Apparent Resistance (Ohm)		
D (ft.)	T1 (Northeast to Southwest)	T3 (East to West)	T4 (North to South)
0.5	27.89	61.25	15.91
1.0	18.73	25.02	12.71
1.5	15.15	21.54	0.2433
2.0	9.463	16.78	4.995
3.0	3.416	10.60	7.708
5.0	2.616	7.443	3.125
7.0	1.716	6.779	1.447
10.0	1.056	5.785	1.198
15.0	1.773	4.673	1.038
20.0	0.5155	3.983	0.9335
30.0	0.3620	3.020	0.7451
45.0	0.5406	2.092	0.6081
70.0	0.4649	1.310	0.4801
100.0	0.3228	1.185	0.4987
150.0	0.2203	1.172	0.4027
200.0	0.1824	1.285	0.3107
300.0			0.3143
450.0			0.2806
600.0			0.1716

Table 1 – Apparent Resistance Measurements

*The Apparent Resistance measurements were entered into the CDEGS/RESAP module for the Traverse 1. Based on these inputs, the CDEGS/RESAP module calculated the number, the thickness, and the resistivity of the soil layers. The output for the traverse is shown on the following page.

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Traverse Results Summary

Traverse 1

```
Run ID.....................................: B537
System of Units ...........................: British
Soil Type Selected.........................: Multi-Layer Horizontal
RMS error between measured and calculated...:   22.9096    in percent
resistivities (Note RMS=SQRT(average(Di**2)).
         <--- LAYER CHARACTERISTICS -->   Reflection    Resistivity
 Layer   Resistivity       Thickness     Coefficient    Contrast
Number     (ohm-m)         ( Feet )        (p.u.)        Ratio
======  ==============  ==============  ============  ============
   1      infinite        infinite          0.0           1.0
   2      32.88118        1.832516         -1.0000       0.32881E-18
   3      12.25808        1.799010        -0.45688       0.37280
   4      45.33421        3.427287         0.57432        3.6983
   5      9.761826        11.69842        -0.64564       0.21533
   6      243.3112        44.46784         0.92285        24.925
   7      54.14993        infinite        -0.63592       0.22255
```

Grounding Summary from CDEGS for 40kA Fault

```
Run ID.....................................................:   B537
System of Units ...........................................:  British
Earth Potential/Magnetic Field Calculations.............: Potentials
Number of Energization Source Busses ......................:     1
Current Injected in Reference Source Bus...................:  40000 Amps
Energization Scaling Factor (SPLITS/FCDIST/specified)..:   1.0000
Number of Original Conductors .............................:    703
Number of Frequency Values to be Analyzed..................:     1
Power Source Frequency.....................................:   60.000     Hertz
Impedance Values are Based On..............................:   60.000     Hertz
Total Length of Conductor Network..........................:   66855.     feet

CHARACTERISTICS OF MEDIA SURROUNDING NETWORK
============================================
AIR LAYER :  Resistivity.............:  0.100000E+13 ohm-meters
             Relative Permittivity..:   1.00000
             Relative Permeability..:   1.00000

>>> SOIL TYPE : Multi-Layer Horizontal

LAYER RESISTIVITY  |------ RELATIVE -------|   THICKNESS
 No.  (ohm-meter)  Permittivity Permeability    (feet)
----- ------------ ------------ ------------ ------------
    1   32.8812       1.00000       1.00000       1.83252
    2   12.2581       1.00000       1.00000       1.79901
    3   45.3342       1.00000       1.00000       3.42729
    4   9.76183       1.00000       1.00000       11.6984
    5   243.311       1.00000       1.00000       44.4678
    6   54.1499       1.00000       1.00000     0.100000E+11

Case Number................................:     1
Frequency for This Case....................:   60.000      Hertz
GPR of Reference Source Bus (#  1)....Magn..:     2786.763     Volts
                                      Angle.:     12.10192     degrees
Impedance of Grounding System.........Magn..:    0.6966908E-01 Ohms
                                      Angle.:     12.10192     degrees
```

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Safety Report from CDEGS

```
System Frequency.............................(Hertz).:  60.000
System X/R.....................................:  20.000
Surface Layer Thickness.....................(  in ).:  12.000
Number of Surface Layer Resistivities.............:    2
Starting Surface Layer Resistivity.........(ohm-m).:   NONE
Incremental Surface Layer Resistivity.......(ohm-m).:  3000.0
Equivalent Sub-Surface Layer Resistivity....(ohm-m).:  32.881

Body Resistance Calculation..........: IEEE Std.80-2000
Fibrillation Current Calculation.....: IEEE Std.80-2000 (50kg)
Foot Resistance Calculation..........: IEEE Std.80-2000
   User Defined Extra Foot Resistance:   0.0000     ohms
```

Fault Clearing Time (sec)	0.250	0.350	0.500
Decrement Factor	1.101	1.073	1.052
Fibrillation Current (amps)	0.232	0.196	0.164
Body Resistance (ohms)	1000.00	1000.00	1000.00

SURFACE LAYER RESIST-IVITY (OHM-M)	FAULT CLEARING TIME 0.250 sec. STEP VOLTAGE (VOLTS)	0.250 sec. TOUCH VOLTAGE (VOLTS)	0.350 sec. STEP VOLTAGE (VOLTS)	0.350 sec. TOUCH VOLTAGE (VOLTS)	0.500 sec. STEP VOLTAGE (VOLTS)	0.500 sec. TOUCH VOLTAGE (VOLTS)	FOOT RESIST-ANCE: 1 FOOT (OHMS)
NONE	254.0	221.5	220.3	192.1	188.0	164.0	102.8
3000.0	3717.0	1087.3	3223.1	942.8	2751.5	804.9	8319.8

* NOTE * Listed values account for short duration asymmetric waveform
decrement factor listed at the top of each column.

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Ampacity Report from CDEGS

***CDEGS Conductor Ampacity Calculation (per IEEE Standard 80)**

***Ampacity report performed for the 4/0 AWG (ground grid).**

Computation Results

Ampacity (RMS): 43.7344 kA, if no dc offset
41.5839 kA, with maximum dc offset

Input Data

Maximum Fault Duration: 0.5 s

Ambient Temperature: 20 °C

Maximum Allowable Temperature: 1083 °C (Fusing Temperature)

Conductor Size: 4/0 AWG

Conductor Type: Copper, annealed soft drawn (100% conductivity)

Decrement Factor: 1.0517
X/R: 20
Frequency: 60 Hz

Material Constants of Conductor

Name: Copper, annealed soft drawn (100% conductivity)

Reference Temperature for Material Constants: 20.0000 °C

Thermal Coefficient of Resistivity at Reference Temperature: 0.00393 1/ °C

Fusing Temperature of Conductor: 1083.0000 °C

Resistivity of Conductor at Reference Temperature: 1.7200 μΩ·cm

Thermal Capacity per Unit Volume: 3.4200 J/cm³ · °C

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Ampacity Report from CDEGS

***CDEGS Conductor Ampacity Calculation (per IEEE Standard 80)**

***Ampacity report performed for the 500 MCM.**

Computation Results

Ampacity (RMS): 103.3204 kA, if no dc offset
98.2399 kA, with maximum dc offset

Input Data

Maximum Fault Duration: 0.5 s

Ambient Temperature: 20 °C

Maximum Allowable Temperature: 1083 °C (Fusing Temperature)

Conductor Size: 500 MCM

Conductor Type: Copper, annealed soft drawn (100% conductivity)

Decrement Factor: 1.0517
X/R: 20
Frequency: 60 Hz

Material Constants of Conductor

Name: Copper, annealed soft drawn (100% conductivity)

Reference Temperature for Material Constants: 20.0000 °C

Thermal Coefficient of Resistivity at Reference Temperature: 0.00393 1/ °C

Fusing Temperature of Conductor: 1083.0000 °C

Resistivity of Conductor at Reference Temperature: 1.7200 μΩ·cm

Thermal Capacity per Unit Volume: 3.4200 J/cm³ · °C

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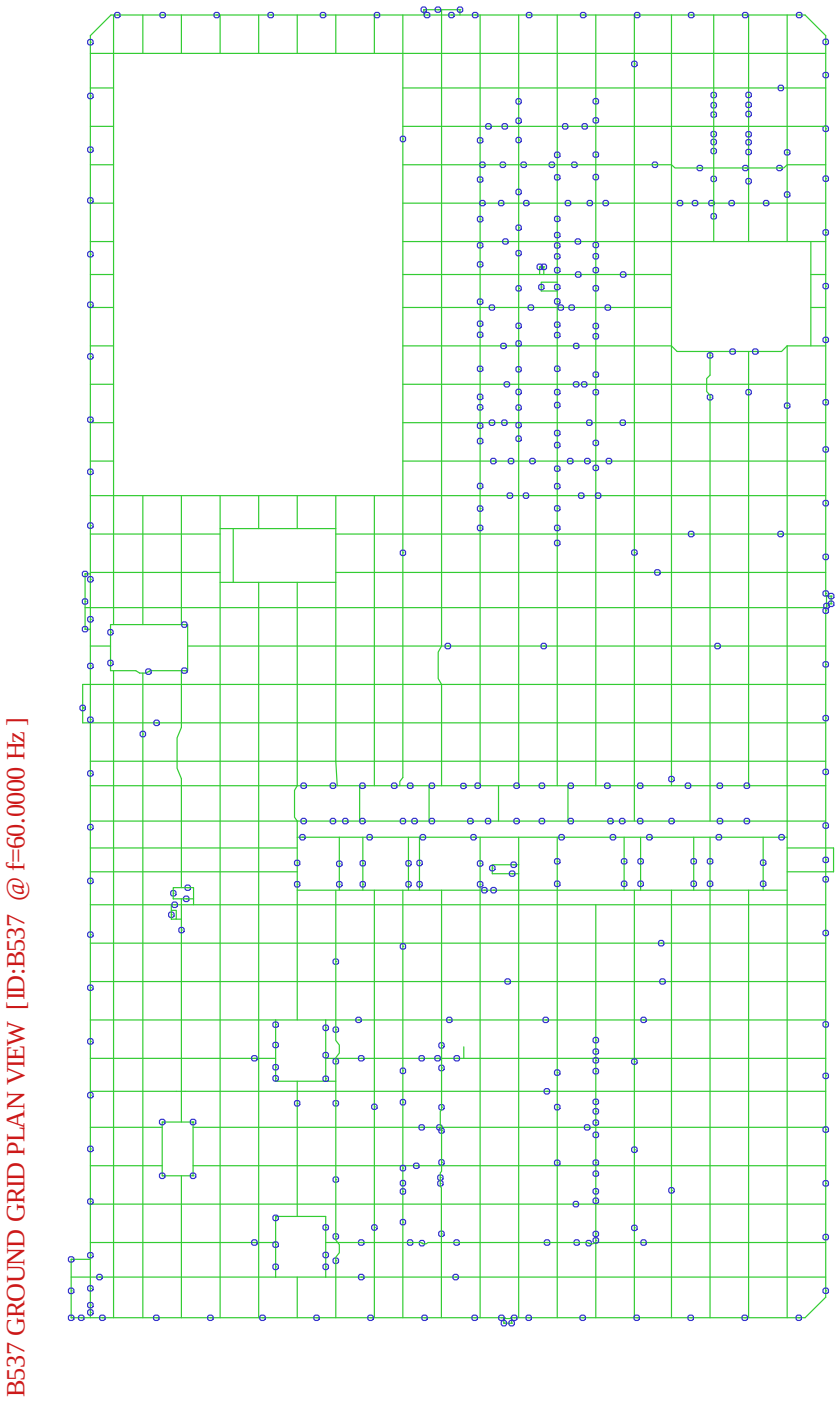
Plan View for Suncrest Substation Ground Grid



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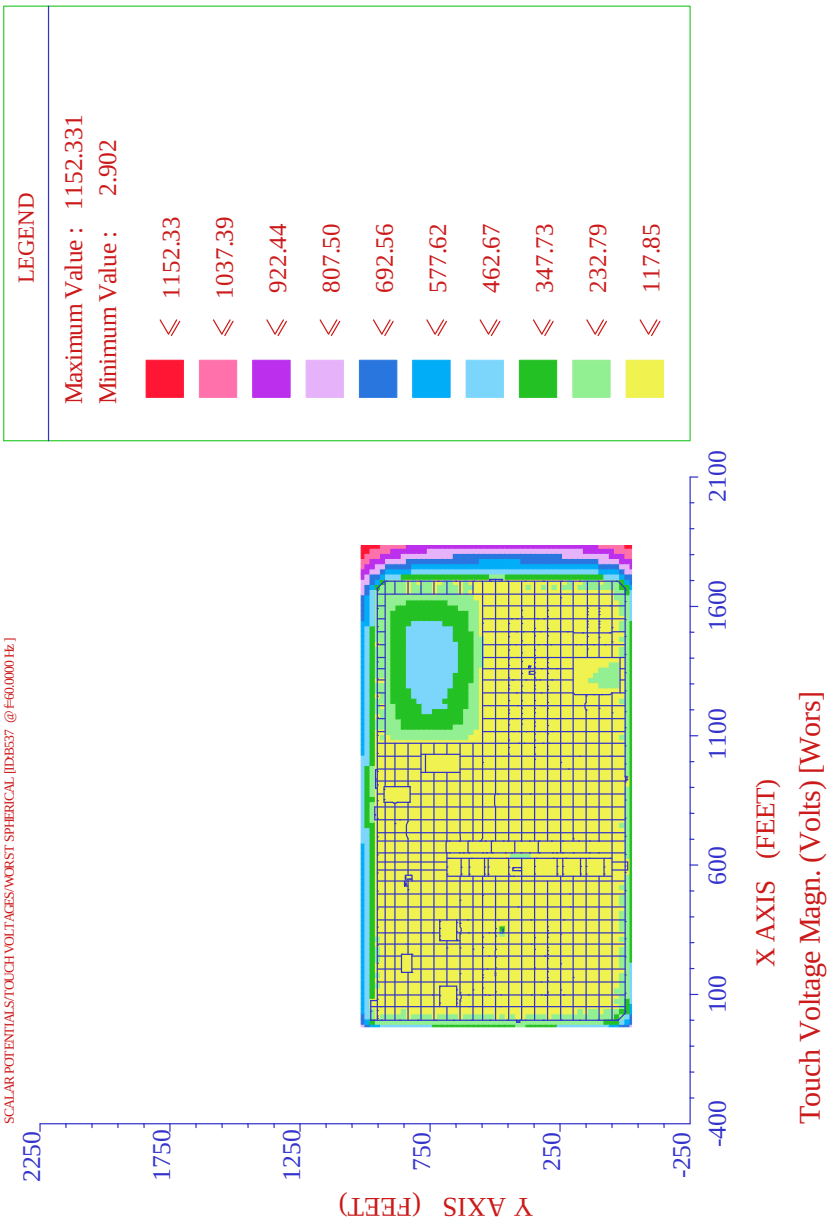
User-Defined Touch Voltages for Suncrest Substation Ground Grid



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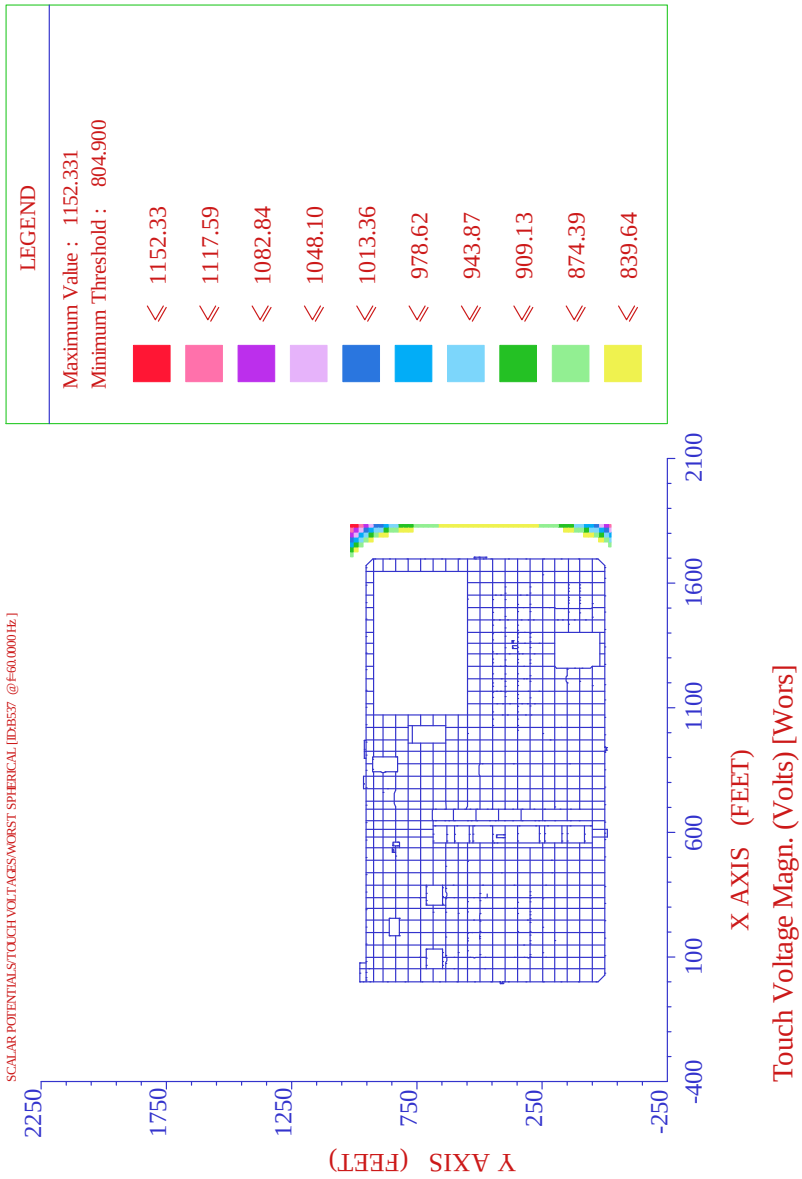
Safety-Limit Touch Voltages for Suncrest Substation Ground Grid



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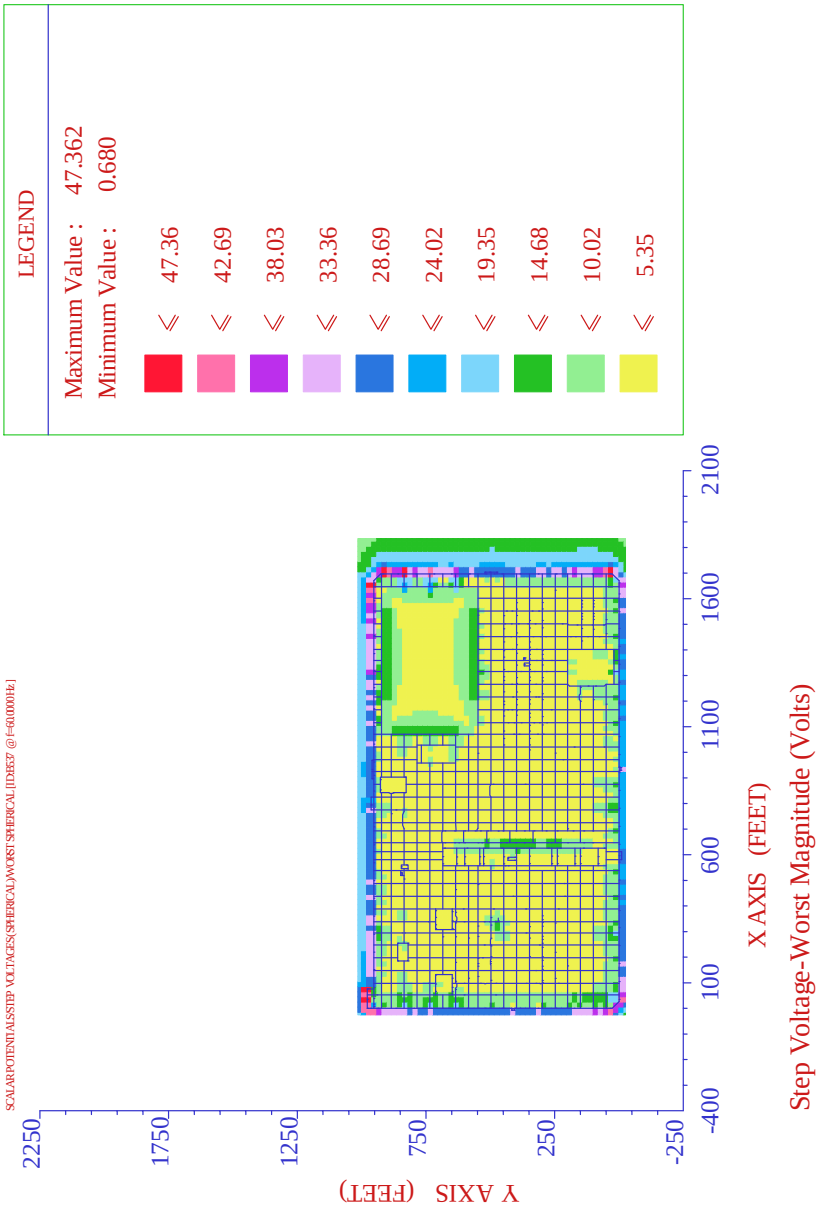
User-Defined Step Voltages for Suncrest Substation Ground Grid



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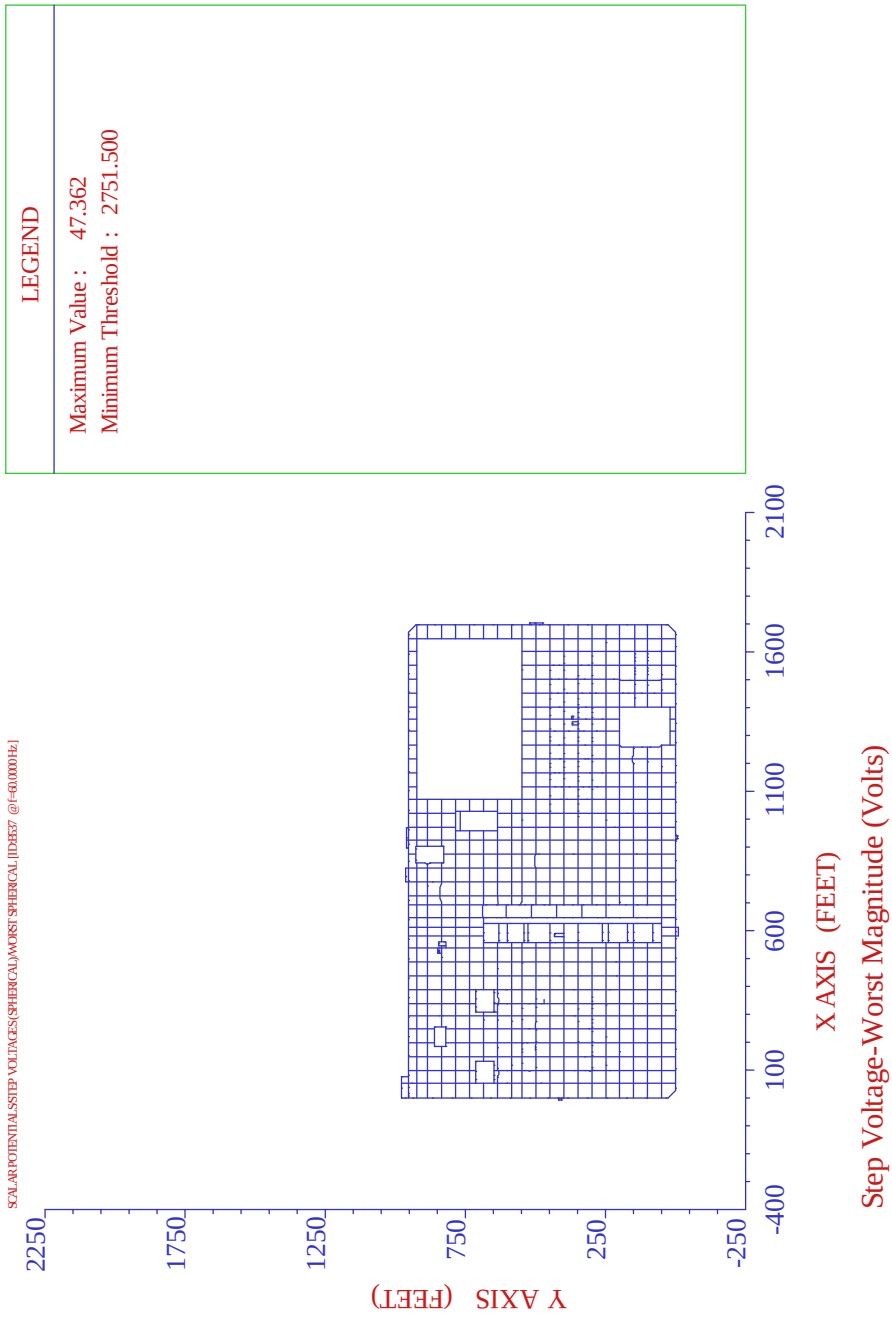
Safety-Limit Step Voltages for Suncrest Substation Ground Grid



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Scalar Potential Profile for Suncrest Substation Ground Grid