Creating a Grounding System Safety Analysis Report Summary with WinIGS

WinIGS provides safety analysis results that follow the requirements of the IEEE std80. The results are in graphical format, i.e. images containing tabular and graphical data, which can be copied and pasted in a report. This document describes a step-by-step procedure for generating a summary report by means of an example. The example files are included in the WinIGS installation directory (path: C:\IGS\DATAU\IGS_AGUIDE_CH02).

Step 1 – Model Report: provide a concise description of the model used in the analysis

The overall WinIGS model in this example consists of a network model, and a geometric grounding model. The network model contains transmission and distribution lines termination at the substation, major power equipment located at the substation, and equivalent sources at the remote ends of the transmission system. For this example, the network model is illustrated in Figure 1.

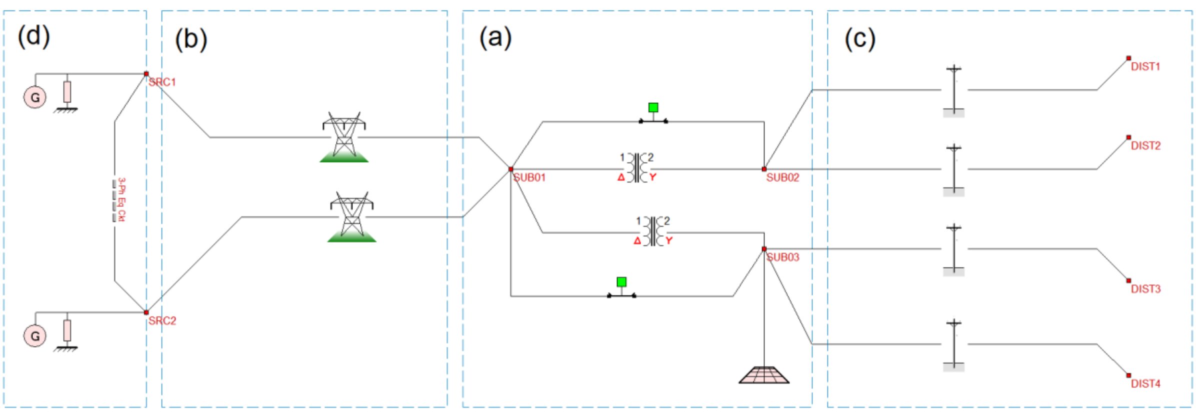


Figure 1: Network Model including (a) Substation of Interest, (b) Transmission System, (c) Distribution System and (d) Equivalent of the Rest of the System

The geometric grounding system model contains a detailed 3-D representation of the ground conductors comprising the substation grounding system. An example geometric grounding model is illustrated in Figure 2.

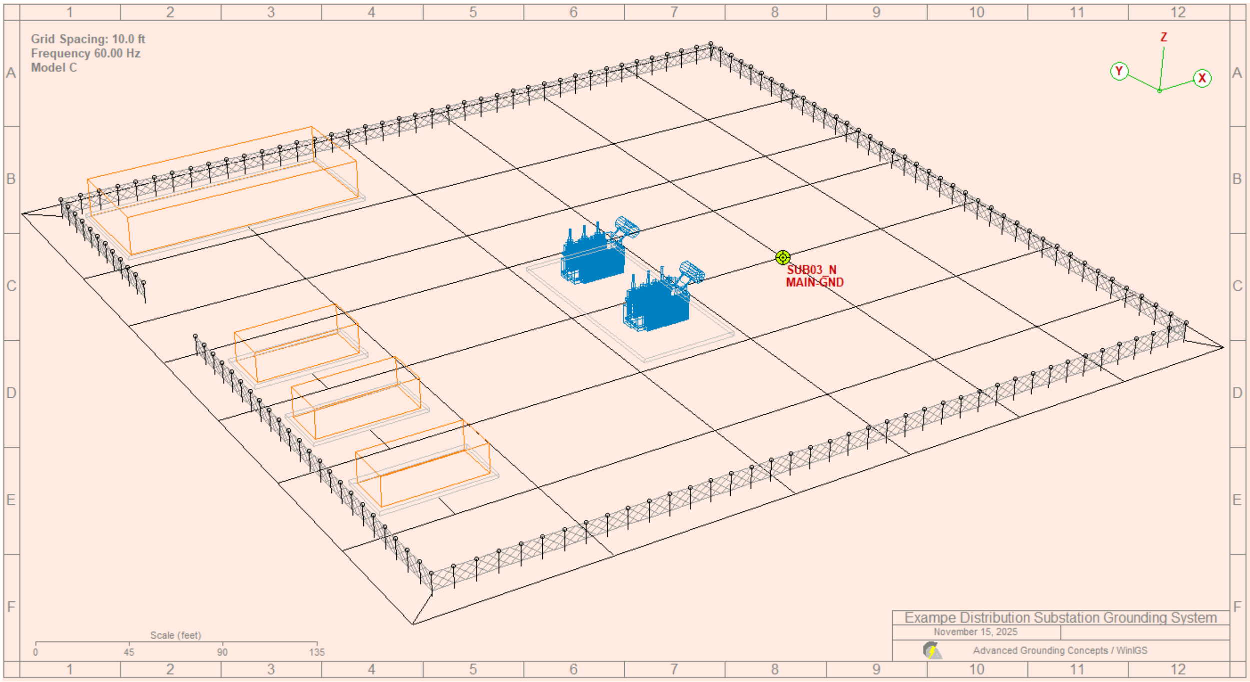


Figure 2: Geometric Grounding Model of Substation of Interest

Step 2 – Maximum GPR Analysis: report the maximum GPR and worst fault condition

Switch to **Analysis** mode, select the **Maximum GPR** analysis function, click on **Run** button, select a node connected to the grounding system of interest (SUB01_N in this example) and click on the **Compute** button (See Figure 3). When the analysis is completed the Maximum GPR Report (Figure 4) shows a description of the fault that generates the highest GPR at the selected node (SUB01_N), namely the fault type, location, GPR, and the fault current.

Use the **Copy** command (see top left of the Max GPR report window in Figure 4) to copy this image into the Windows clipboard. Paste the copied image into your report document. Note that this process can be applied to all report dialogs generated by WinIGS.

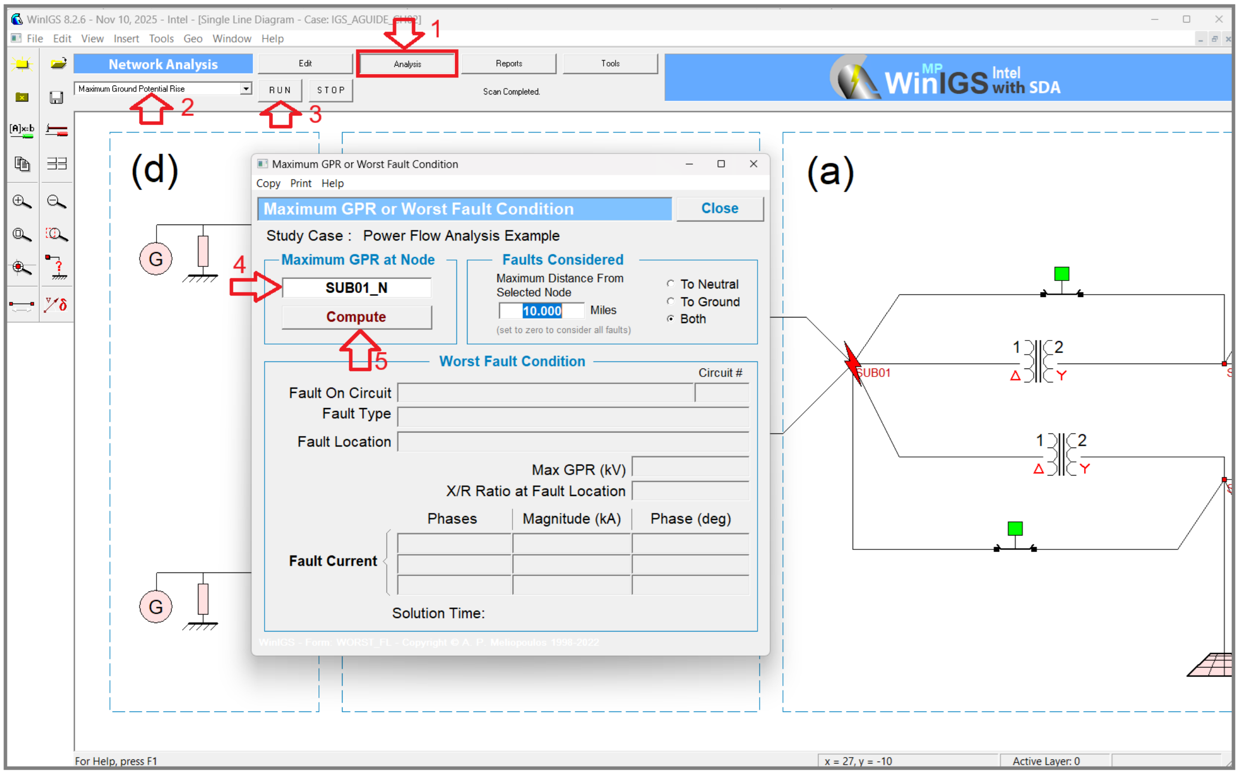


Figure 3: Maximum GPR Analysis

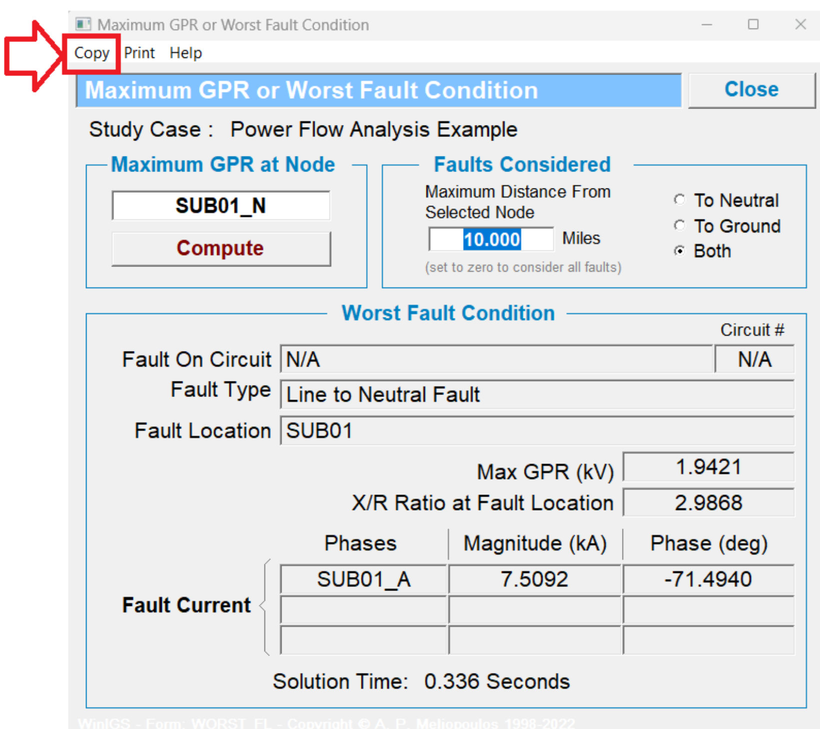


Figure 4: Maximum GPR Analysis and Worst Fault Condition Summary Report

Step 3 – Worst Fault Condition, Split Fact and Permissible Voltage Reports

Click on the **Reports** mode button (See Figure 5). Note that a row of buttons appears along the top of the WinIGS main-frame window, titled *Grounding Resistance, Resistive Layer Effects, Allowable Touch & Step Voltages, Equipotentials & Safety Assessment*, etc. (See arrows numbered 1,2,3 4 in Figure 4). Clicking on each of these buttons opens graphical report windows, which provide the detailed results of the Maximum GPR analysis. It is recommended to sequentially click on buttons 1,2,3, and 4 and copy and paste the resulting dialog windows into your report document. A description of these report dialog windows follows.

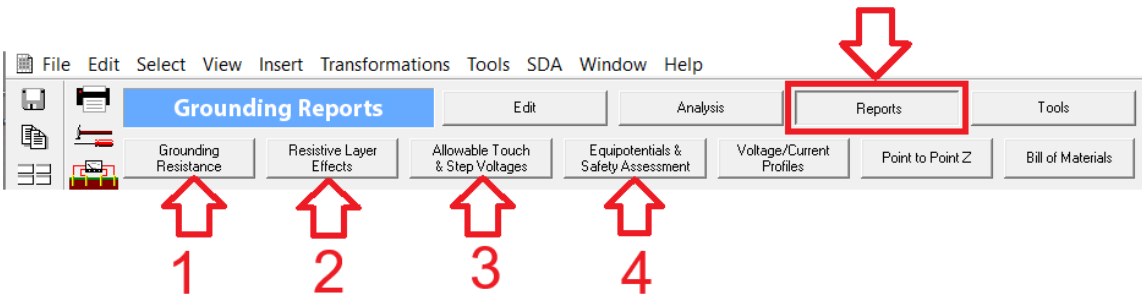


Figure 5: Reports Mode Toolbar

1. The **Grounding Resistance** button opens the report window illustrated in Figure 6. This window shows the impedance of the substation grounding system resistance (0.8184 Ohms) and optionally reactance (0.0076 Ohms), the ground potential rise (1850 V) and the current injected into the ground via the substation ground grid (2261 A) and the split factor. Note that if the grounding model contains multiple node interface objects, there will be a row of these data for each node interface. This report shows the earth current (2261 A) that flows from the grounding system into the soil, the fault current (7155 A) and the split factor (31.6%).

In this example, the table entries Rp = 0.8184 and Xp = 0.0076 are equal to the grounding system resistance and reactance. In cases where multiple node interface elements exist, the Rp and Xp values give the impedance into the grounding system if the node interface location were bonded together.

Use the dialog Window's **Copy** command to copy and paste the window image into your report document.

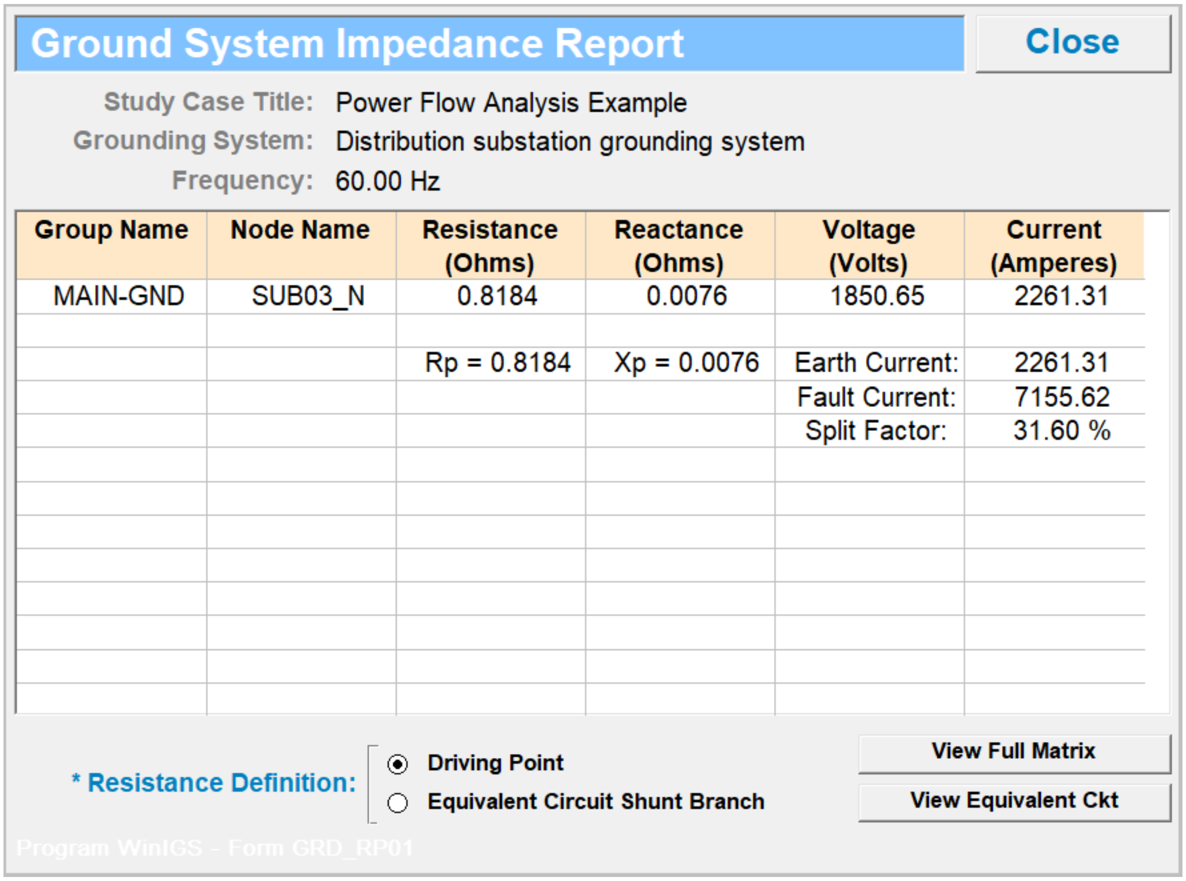


Figure 6: Grounding System Impedance Report

2. The **Resistive Layer Effects** button opens the reduction factor window illustrated in Figure 7. In this window, you can specify the resistivity and thickness of an insulating layer that covers the substation area. These values determine the reduction factor as defined in the IEEE-Std.80, or optionally the IEC-Std.60479. The reduction factor affects the permissible touch and step voltages. Note that these curves differ in various IEEE standard versions, and the radio buttons at the top right of this window allow selection of the IEEE standard to be used. It is recommended to select the latest IEEE version.

Use the dialog Window's **Copy** command to copy and paste the window image into your report document.

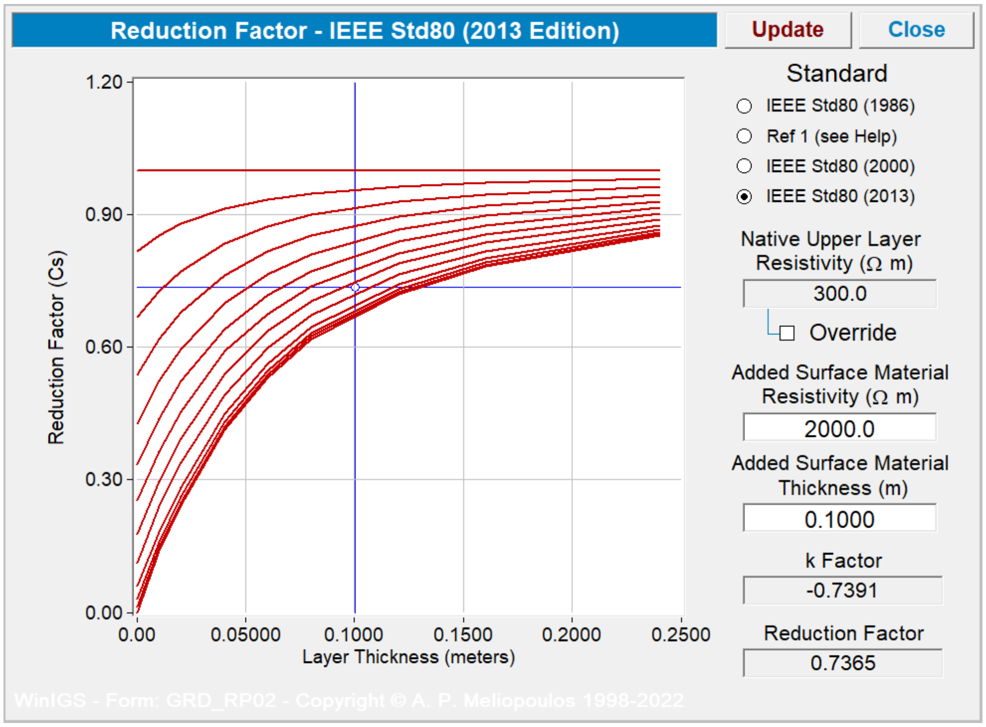


Figure 7: Selection of Surface Material for the Computation of Permissible Touch and Step Voltages

3. The **Allowable Touch & Step Voltages** button opens the window illustrated in Figure 8. In this window, you can set the "***Electric Shock Duration***" (set to 0.5 seconds in this example). The electric shock duration is typically set to the time taken by the backup protection system to interrupt the fault. This value determines the permissible body current, according to the selected standard (IEEE-Std. 80 or IEC-Std. 60479). The IEEE-Std.80 defines the permissible body current for 50 and 70 kg persons. Radio buttons on this form allow selection of the standard, body weight etc.

The selected shock duration, standard, body weight, the X/R ratio at the fault location, as well as the surface material used described above determine the ***permissible touch and step voltages***. These values are listed in the bottom half of this form.

Note that the X/R ratio is automatically computed by WinIGS during the fault analysis. However, you can override the computed value using the radio button located next to the entry field titled **User Defined X/R Ratio**. (not recommended).

Note also that the permissible touch and step voltages are reported for two conditions: for persons standing in areas covered by the specified surface material, and for persons standing on native soil. Radio buttons located next to the corresponding values permit selection of the desired permissible values. It is recommended to select the native soil option for the permissible step voltage, since the maximum step voltages typically occur outside the substation perimeter, where the insulating surface material may not exist.

Use the dialog Window's **Copy** command to copy and paste the window image into your report document.

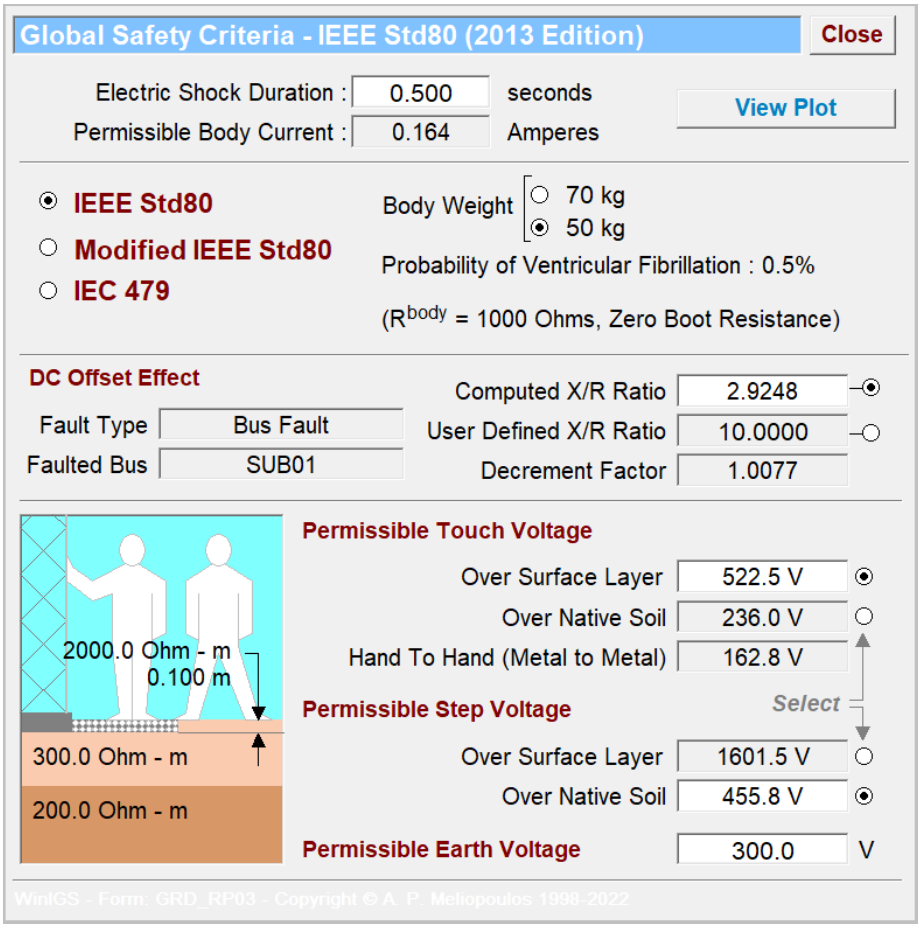


Figure 8: Safety Criteria Report

Step 4 – Graphical Touch and Step Voltage Reports

Click on the **Equipotentials & Safety Assessment** button (See arrow 4 in Figure 5). Select the **Touch Voltage** radio button (Arrow 1 in Figure 9).

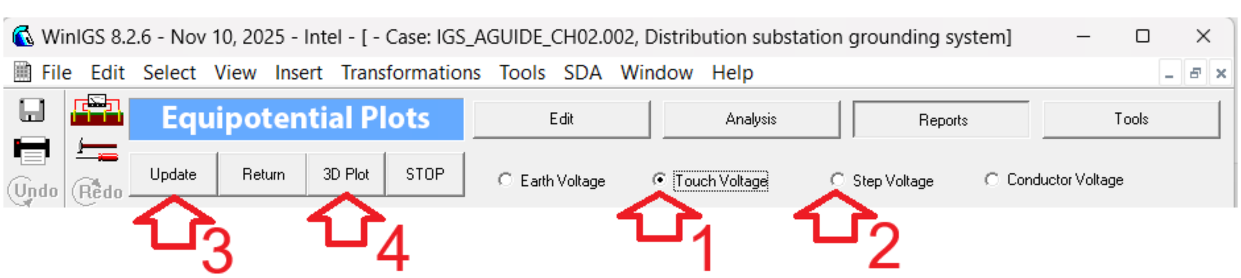
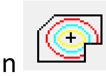


Figure 9: Equipotential Plots Toolbar

Define the region over which the actual touch and step voltages should be computed. This is accomplished using an equipotential plot frame object. Use the vertical toolbar button  to create an equipotential frame object. Note that this is a polygonal line created by left clicking on the polygon vertices. Use the right mouse button to terminate vertex entry. The polygon vertices can be edited (moved, added deleted etc. using the mouse). Furthermore, the polygon can be automatically set to enclose selected fence models.

Left double-click of the equipotential frame perimeter to open the plot frame properties dialog. This dialog, shown in Figure 10, contains several controls that affect the applied permissible voltages, the touch voltage reference, the plotting format, resolution and color selection. The **Auto-Set** button provides an option to automatically set the polygonal frame to enclose a set of fences. One or more fence elements must be selected before clicking on this button. Additional details regarding these controls can be found in the WinIGS user's manual. Click on the Accept button to close the plot frame properties dialog.

Figure 10: Equipotential Plot Polygonal Frame Properties

Next, click on the Touch Voltage radio button (Arrow 1 in Figure 9), the **Update** button (Arrow 3 in Figure 9). This action generates a graphical representation of the touch voltage distribution in terms of equipotential curves covering the area within the equipotential plot frame(s). The touch voltage equipotential plot for this example is illustrated in Figure 11. Note that the numeric values of the permissible touch voltage (522.4V) and the maximum value of the actual touch voltage (575.9V) are listed on the legend located above the equipotential plot. The margin shown in % is computed as follows:

$$\text{Margin} = (T_{max} - T_{perm}) / T_{max}$$

The margin is negative if the maximum value exceeds the permissible value. Note that the legends can be repositioned as needed using the mouse.

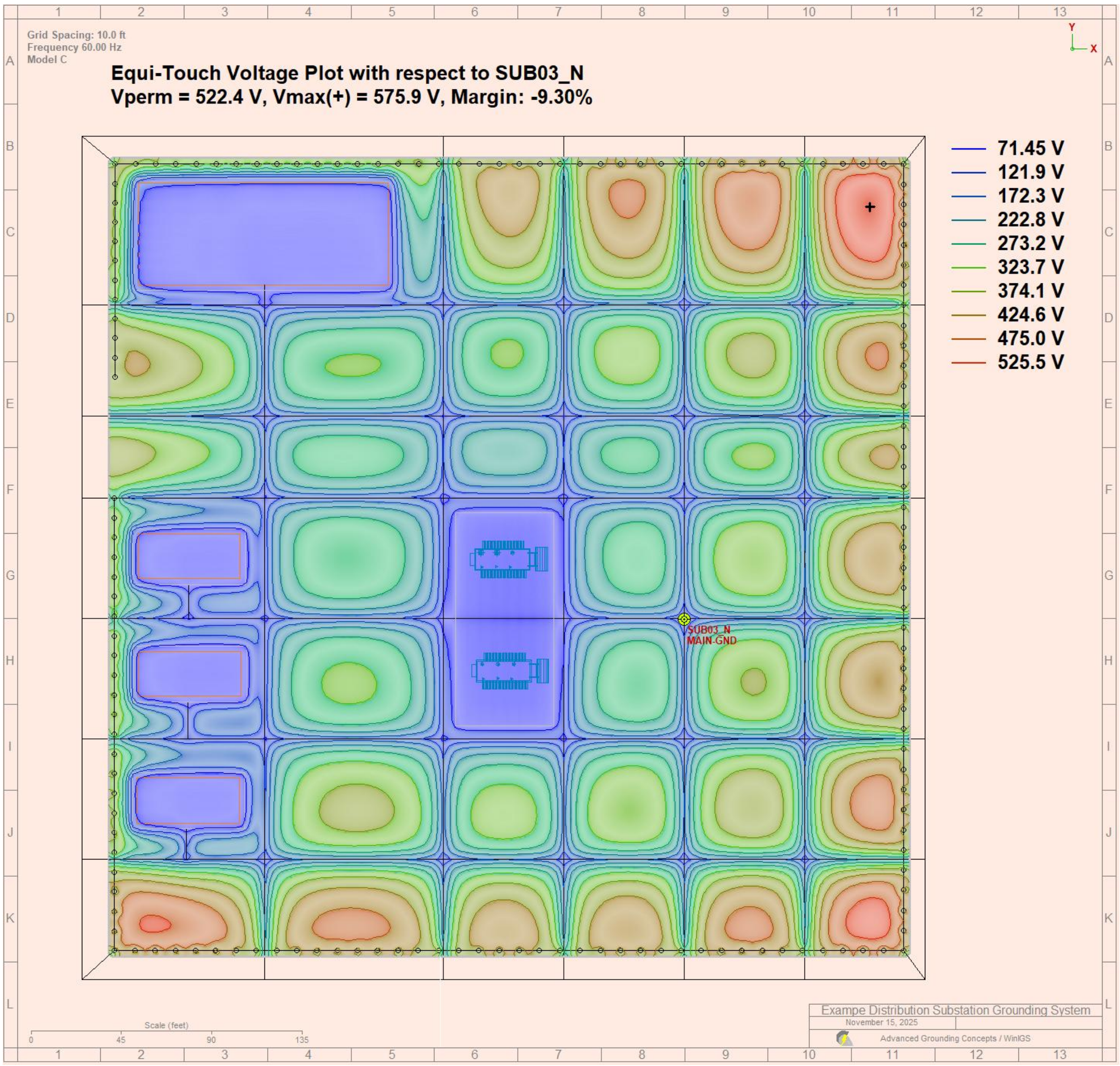
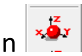


Figure 11: Touch Voltage Equipotential Curve Report

The displayed equipotential line plot can be copied to a report document using the **Copy Drawing** command of the **Edit** pull-down menu via the Windows clipboard (See Figure 12).

An alternate form of touch voltage visualization can be generated using the toolbar button . This button opens a 3-D rendered view of the grounding system model with the touch voltage represented by a color coded surface plot (See Figure 13). The colors of the 3-D surface can be selected using the toolbar button . The displayed 3-D surface plot be copied to a report document using the **Copy Drawing** command of the **Edit** pull-down menu via the Windows clipboard.

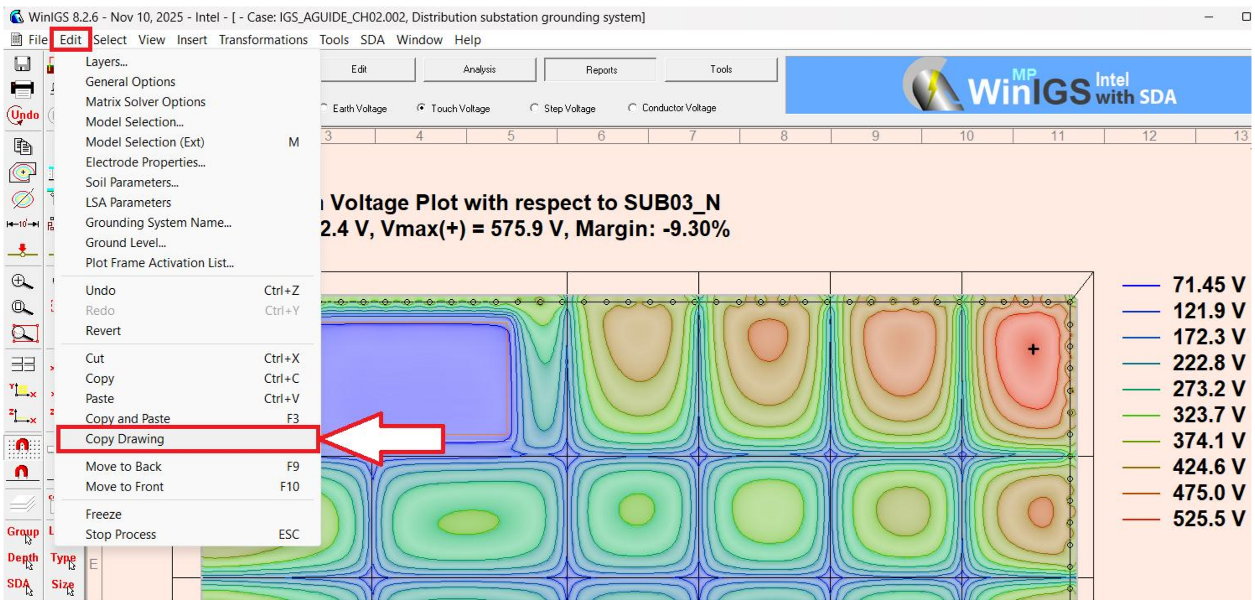


Figure 12: Copying the 2-D Equipotential Plot to the Windows Clipboard

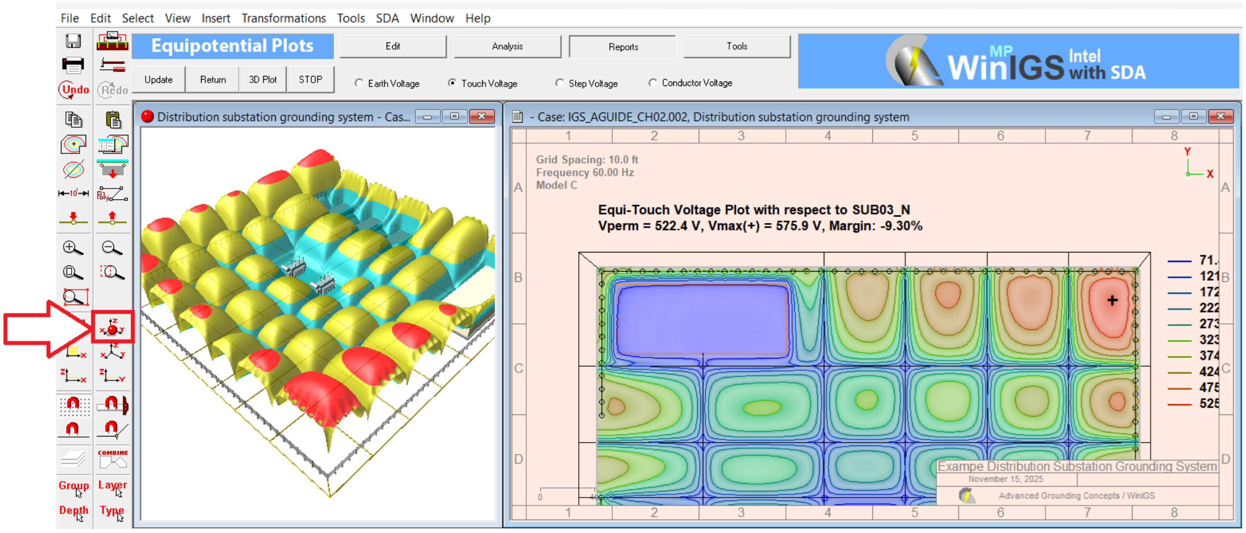


Figure 13: Opening the Touch Voltage 3-D Surface Plot View

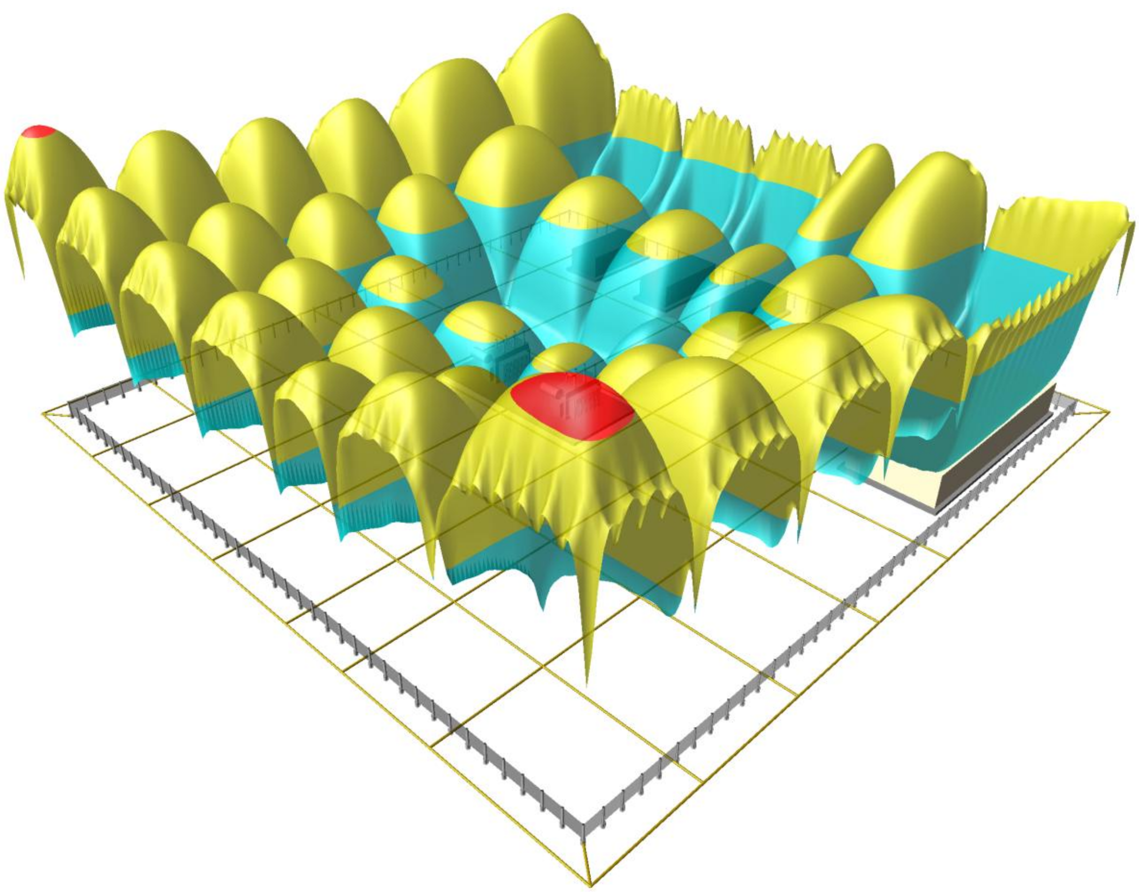


Figure 14: Touch Voltage Equipotential Curve Report

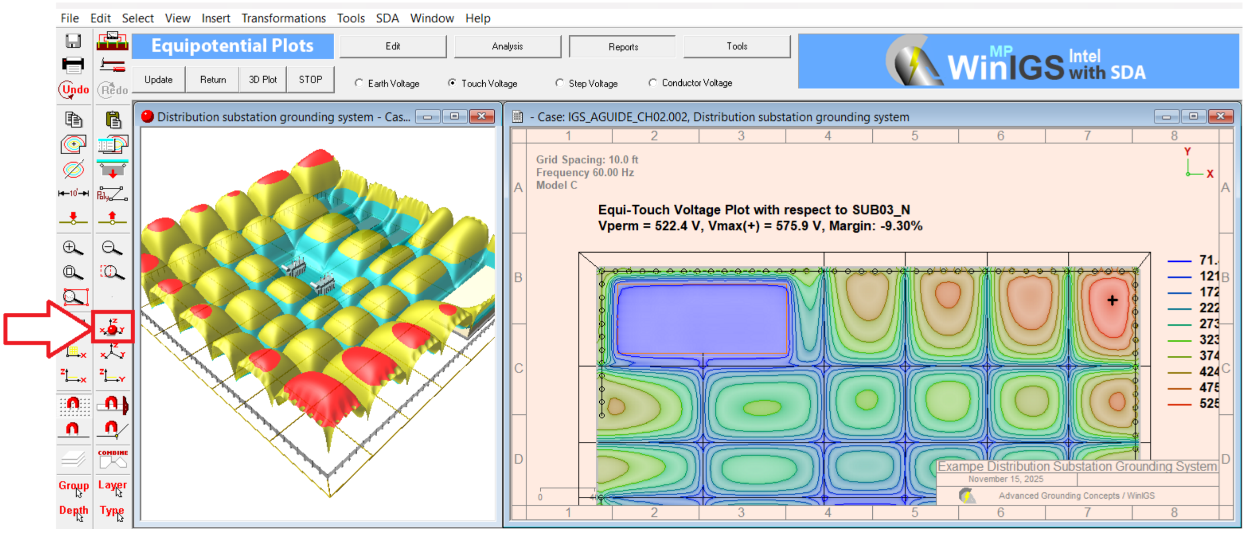
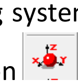


Figure 15: Touch Voltage Equipotential Curve Report

Similarly, step voltage 2-D and 3-D plots can be generated and copied to a report document, as follows. Close the 3-D rendered view, click on the **Step Voltage** radio button (Arrow 2 in Figure 9), and the **Update** button (Arrow 3 in Figure 9). This action generates a graphical representation of the step voltage distribution in terms of equipotential curves covering the area within the equipotential plot frame (See Figure 17). Note that the equipotential frame defined for step voltage plotting covers only a narrow band outside the perimeter fence. The reason for this selection is that maximum step voltages typically occur a few feet outside the perimeter fence.

The 3-D rendered view of the grounding system model with the superimposed surface plot of the step voltage is opened using the toolbar button  (See Figure 18). The displayed equipotential step voltage plot can be copied to a report document using the **Copy Drawing** command of the **Edit** pull-down menu via the Windows clipboard.

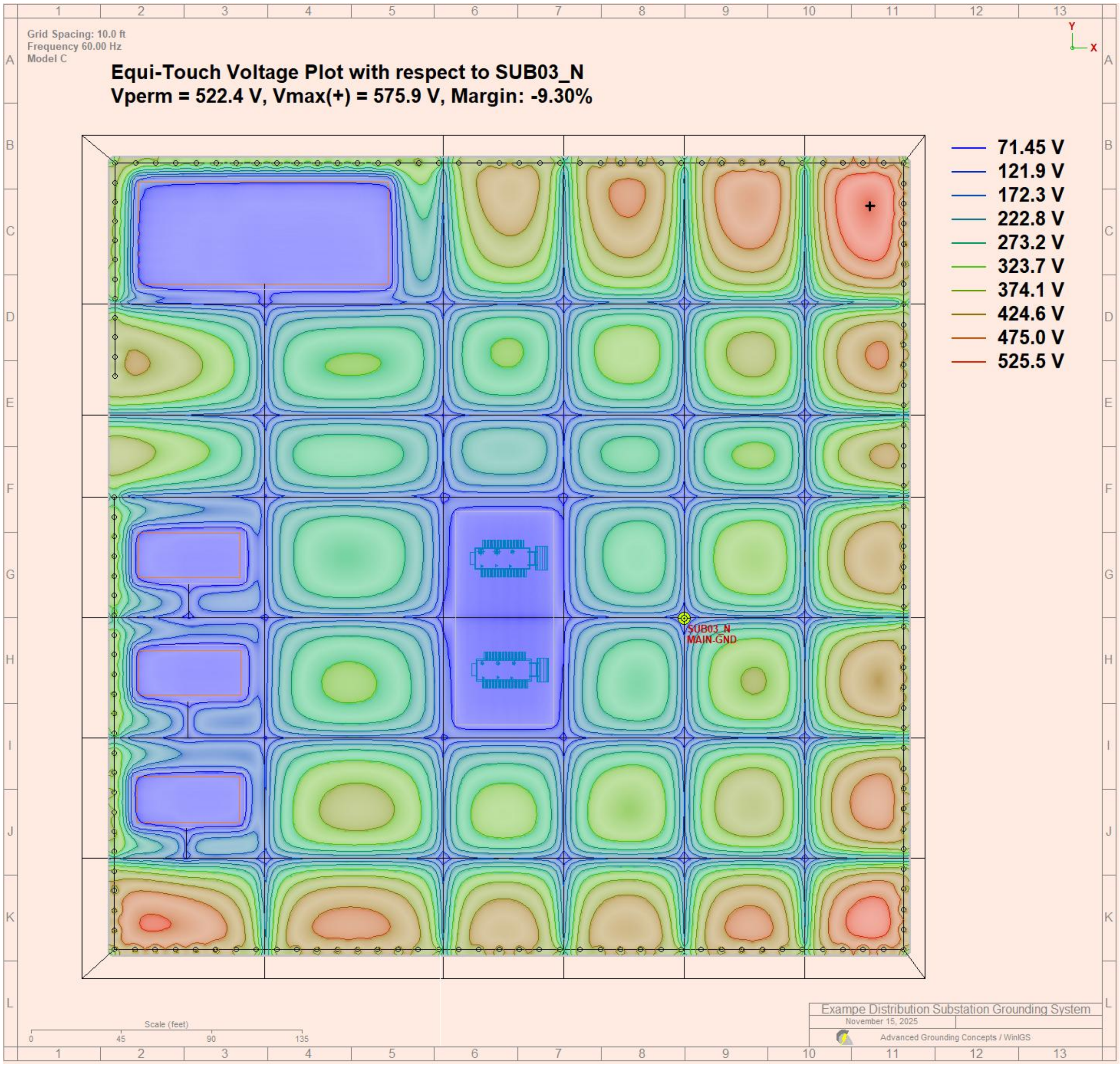


Figure 16: Touch Voltage Equipotential Curve Report

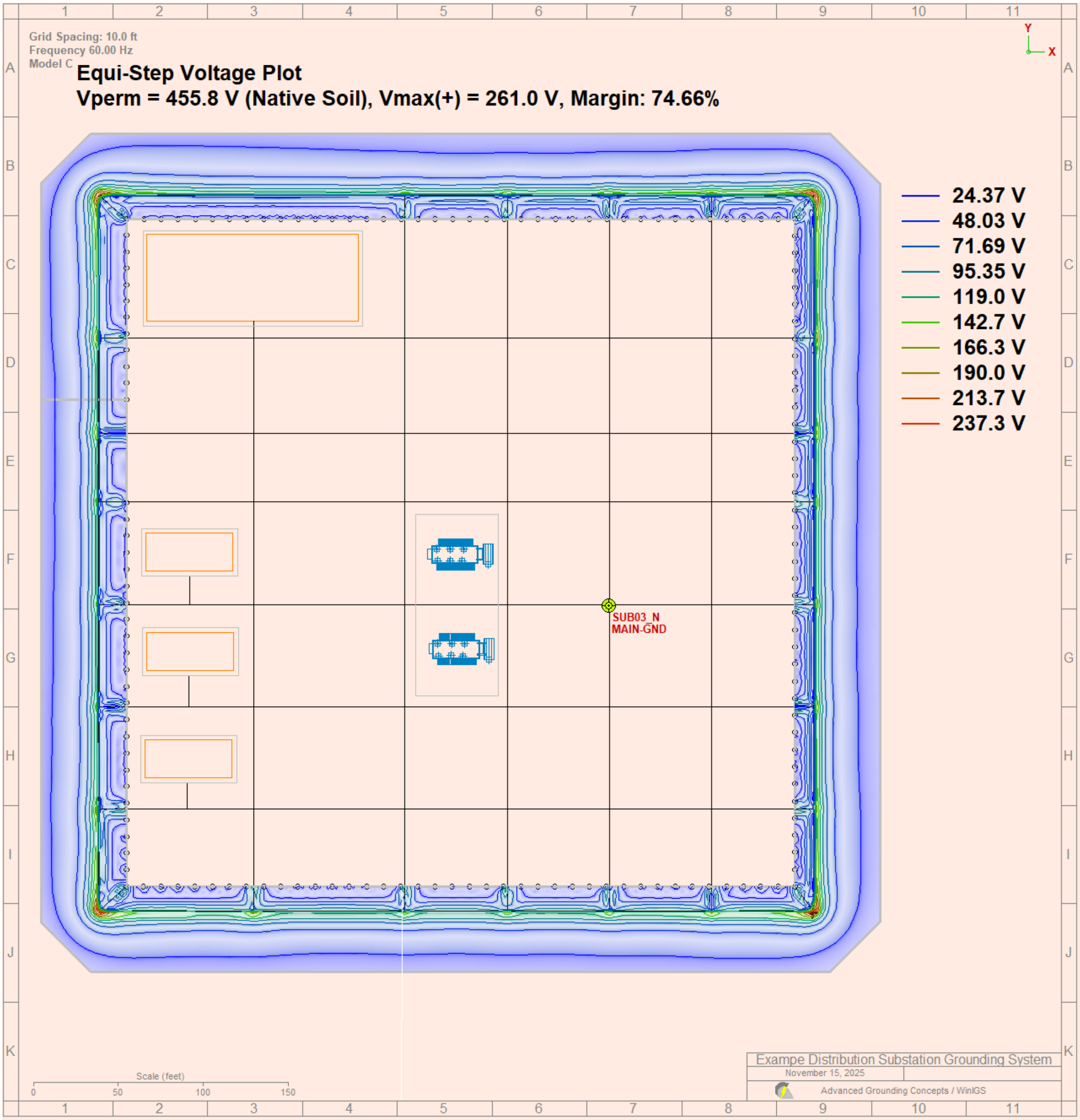


Figure 17: Step Voltage Equipotential Curve Report

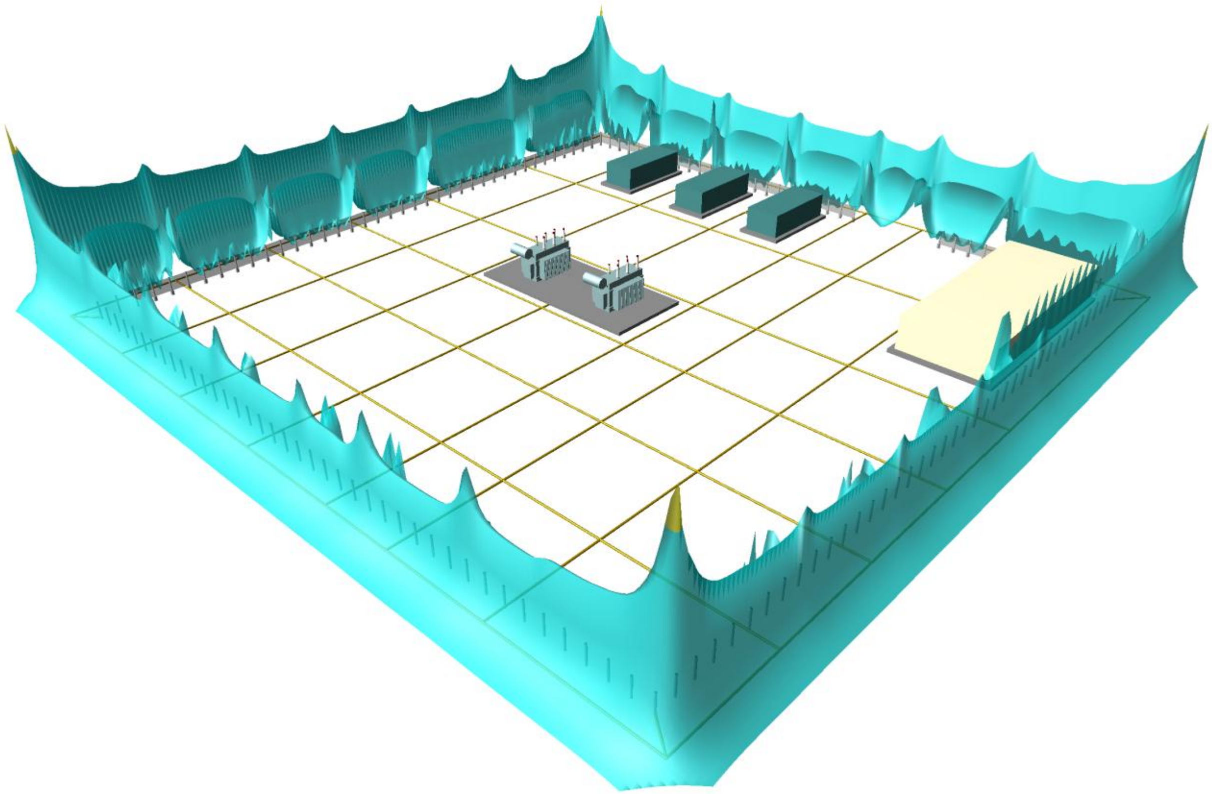


Figure 18: Step Voltage Equipotential Curve Report