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Testing Grounding Systems

- Why
- How to Specify
- How to Test

Why do we test Grounding Systems?

- We all know that exposure to electrical shock can kill you; is that not enough?
- We have design engineers doing their best to design a safe installation, but is it safe?
- It's safe for humans, but what about the installed equipment?

Why do we test Grounding Systems?

Per IEEE Std 81-2012:

- To verify adequacy of new grounding system
- To determine if there are any changes to an existing grounding system
- To identify hazardous touch and step voltages
- To determine Ground Potential Rise (GPR) for protecting communications circuits.

How to Specify

We see numerous testing specifications come though our office

- Some specify Ohm values for selected items of interest
- 99% of the specifications detail the method of test as Fall of Potential method

So what's the problem?

How to Specify – some examples

3.7 FIELD QUALITY CONTROL

A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

B. Tests and Inspections:

1. After installing grounding system but before permanent electrical circuits have been energized, test for compliance with requirements.
2. Inspect physical and mechanical condition. Verify tightness of accessible, bolted, electrical connections with a calibrated torque wrench according to manufacturer's written instructions.
3. Test completed grounding system at each location where a maximum ground-resistance level is specified, at each service disconnect enclosure grounding terminal, at ground test wells. Make tests at ground rods before any conductors are connected.
   a. Measure ground resistance no fewer than two full days after last trace of precipitation and without soil being moistened by any means other than natural drainage or seepage and without chemical treatment or other artificial means of reducing natural ground resistance.
   b. Perform tests by fall-of-potential method according to IEEE 81.
   c. If resistance to ground exceeds the following specified values, notify Architect promptly and include recommendations to reduce ground resistance.
      1) Service entrance main ground: 10 ohms.
4. Prepare dimensioned Drawings locating each test well, ground rod and ground-rod assembly, and other grounding electrodes. Identify each by letter in alphabetical order, and key to the record of tests and observations. Include the number of rods driven and their depth at each location, and include observations of weather and other phenomena that may affect test results. Describe measures taken to improve test results.

C. Prepare test and inspection reports.

END OF SECTION

How to Specify – some examples

B. Testing Agency: Engage a qualified testing and inspecting agency to perform the following field tests and inspections and prepare test reports:

1. After installing grounding system but before permanent electrical circuits have been energized, test for compliance with requirements.
2. Test completed grounding system at each location where a maximum ground-resistance level is specified, at service disconnect enclosure grounding terminal, at ground test wells, and at individual ground rods. Make tests at ground rods before any conductors are connected.
   a. Measure ground resistance not less than two full days after last trace of precipitation and without soil being moistened by any means other than natural drainage or seepage and without chemical treatment or other artificial means of reducing natural ground resistance.
   b. Perform tests by fall-of-potential method according to IEEE 81.
3. Prepare dimensioned drawings locating each test well, ground rod and ground rod assembly, and other grounding electrodes. Identify each by letter in alphabetical order, and key to the record of tests and observations. Include the number of rods driven and their depth at each location, and include observations of weather and other phenomena that may affect test results. Describe measures taken to improve test results.
4. Conduct three separate tests on opposite sides of grounding grid.

How to Test

What are the problems with the existing specifications?

Are there any problems with the tried and tested Fall of Potential (FoP) method?

Specification Issues

- Typically only mentions the FoP testing methodology
- Fails to include a requirement that would rule out the FoP method; is the grounding system to be tested totally isolated from any external grounds?
- Specifying specific values for a grounding system might not result in a totally safe installation

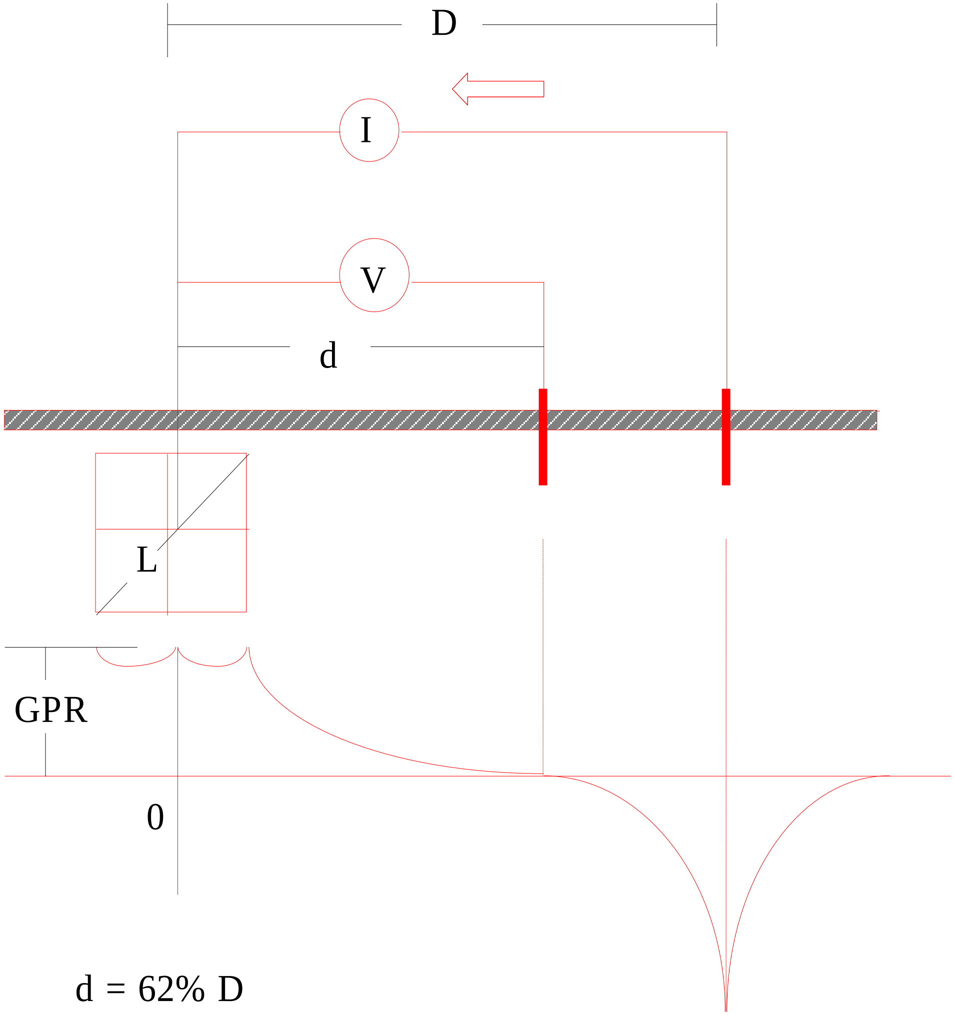
Methods for Testing

- Fall-Of-Potential Method
- Computer Based Grounding Multimeter Method

Fall of Potential

- Developed in the 1950s when we were less congested
- Does not work well on large ground systems or odd shaped grounding areas
- Ground under test must be isolated – no O/H Statics or Neutrals bonded to ground grid
- No connection from construction supply neutral to site ground
- No error correction for induced voltages and noise
- Small data set
- No statistical analysis

Fall of Potential Set Up

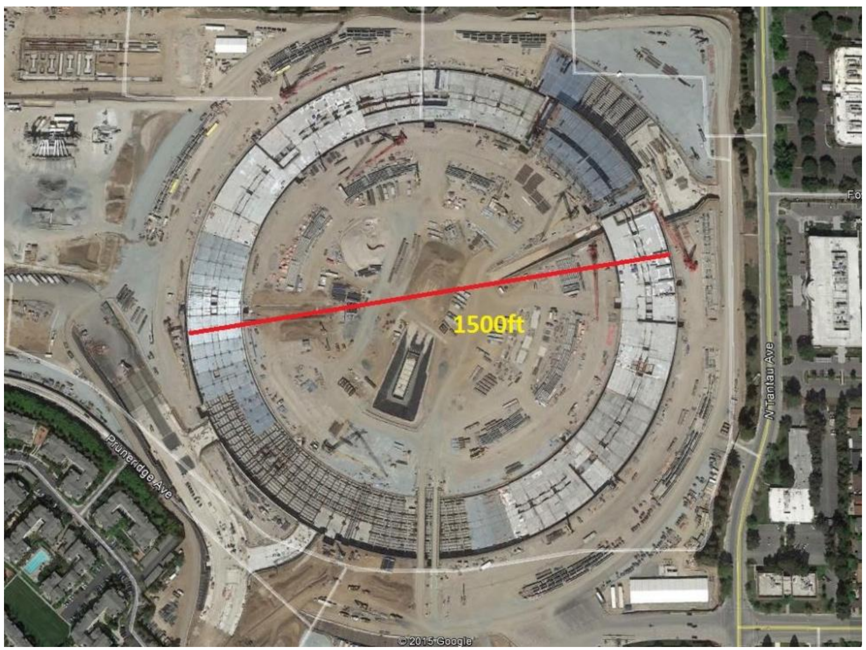


d = 62% D
D = 5 x L

Fall of Potential Set Up

Isolate the ground to be tested.

Set up the various probes.

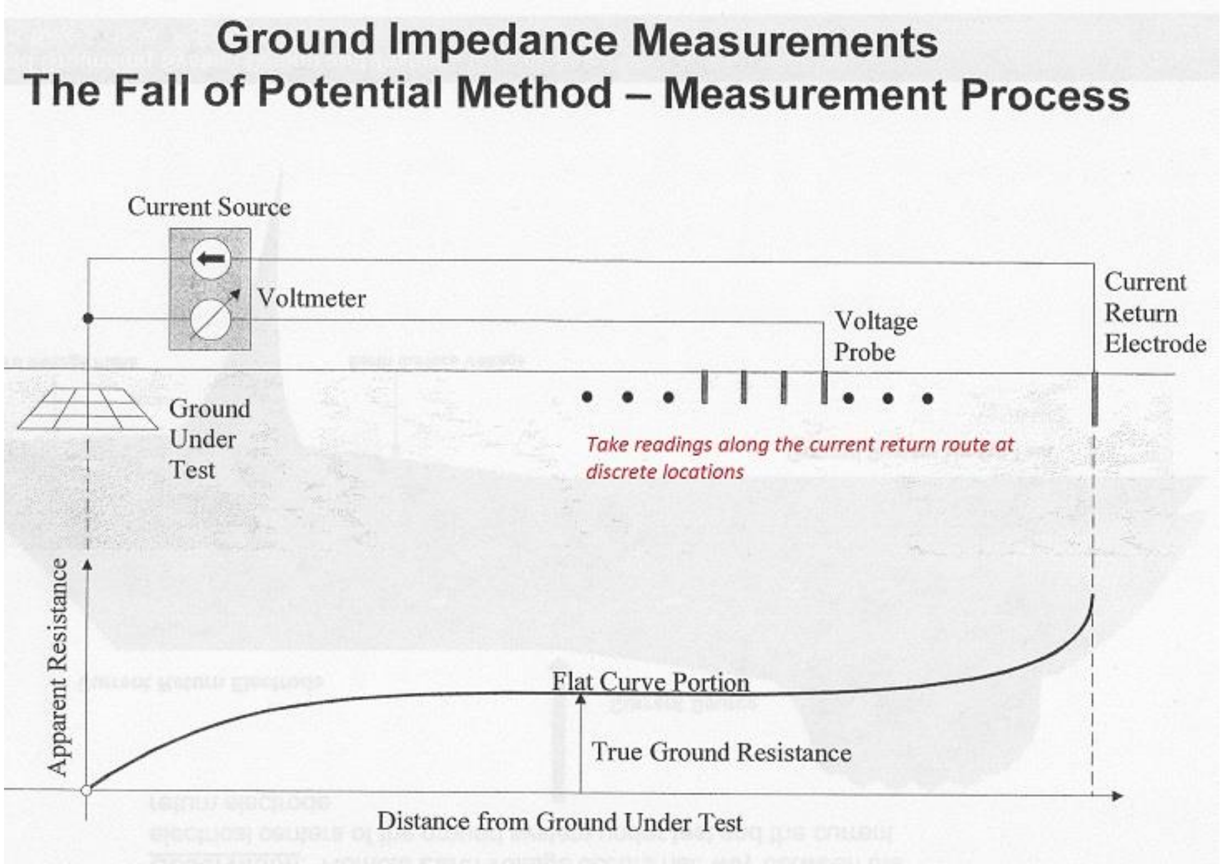


Rule 1: Current at 5 times diagonal of site

Rule 2: Voltage probe varied from 50% to 70% of distance to current probe

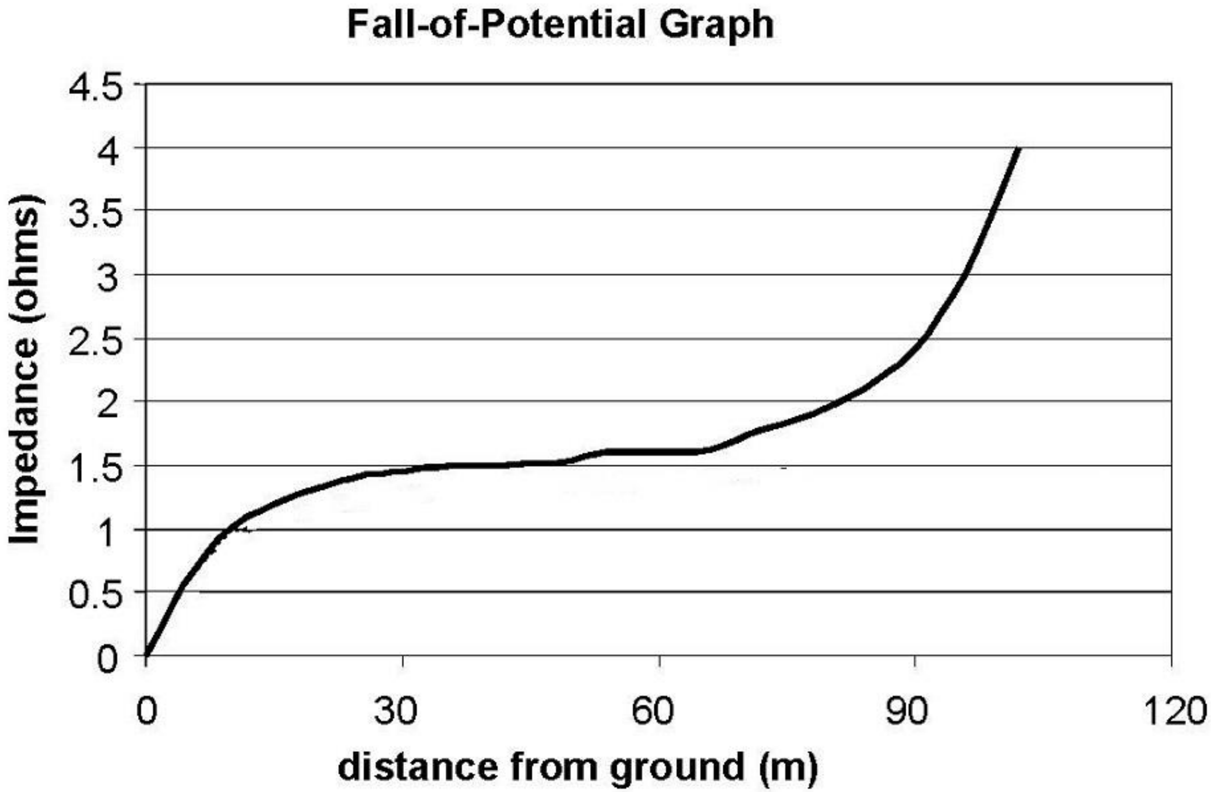
Fall of Potential Results

Ideal results from an isolated ground FoP test



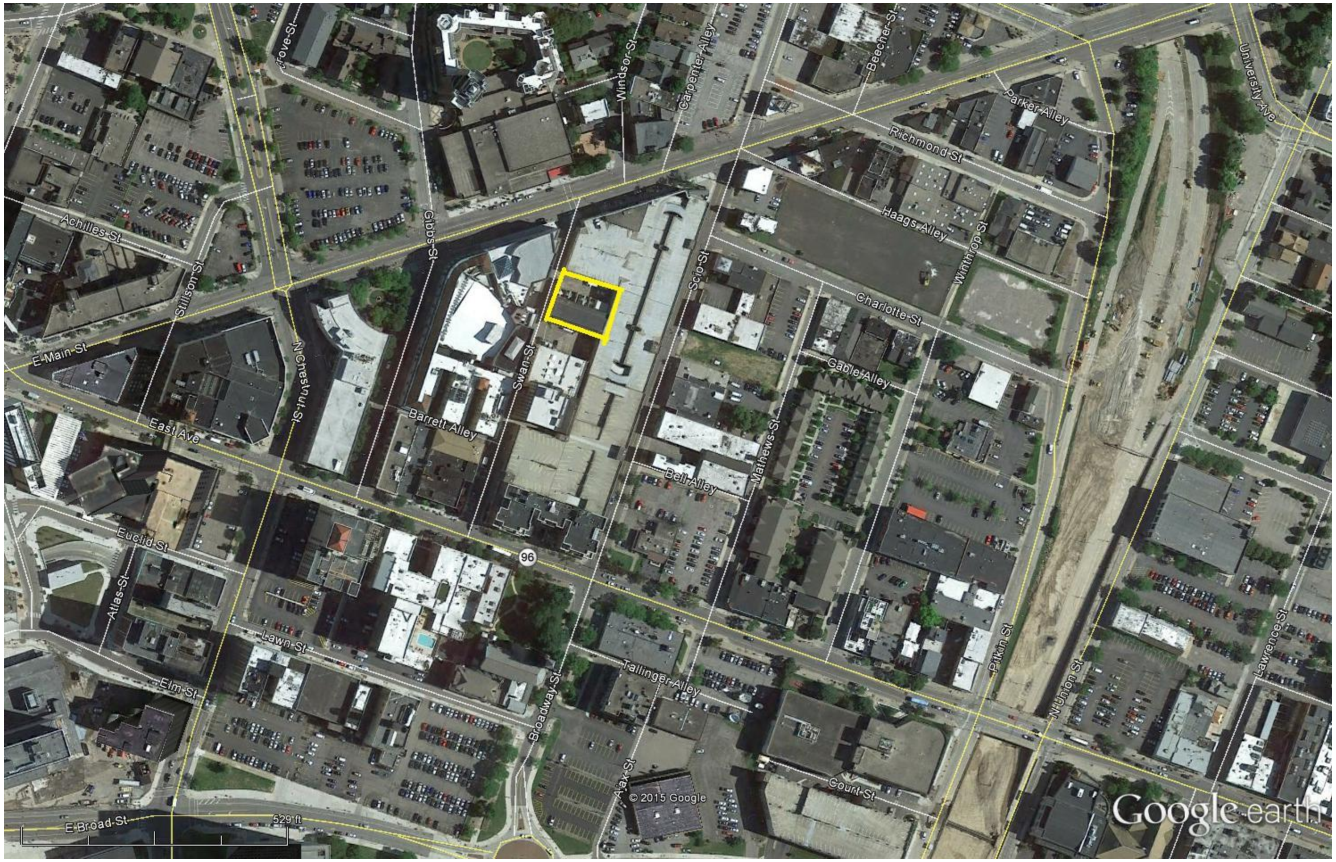
Fall of Potential Results

Typical results from an isolated ground FoP test



FoP Limitations

Downtown congested area



FoP Limitations

Large site - already bonded and energized

Alternative Test Method

IEEE Std 81-2012 addresses the shortcomings of FoP

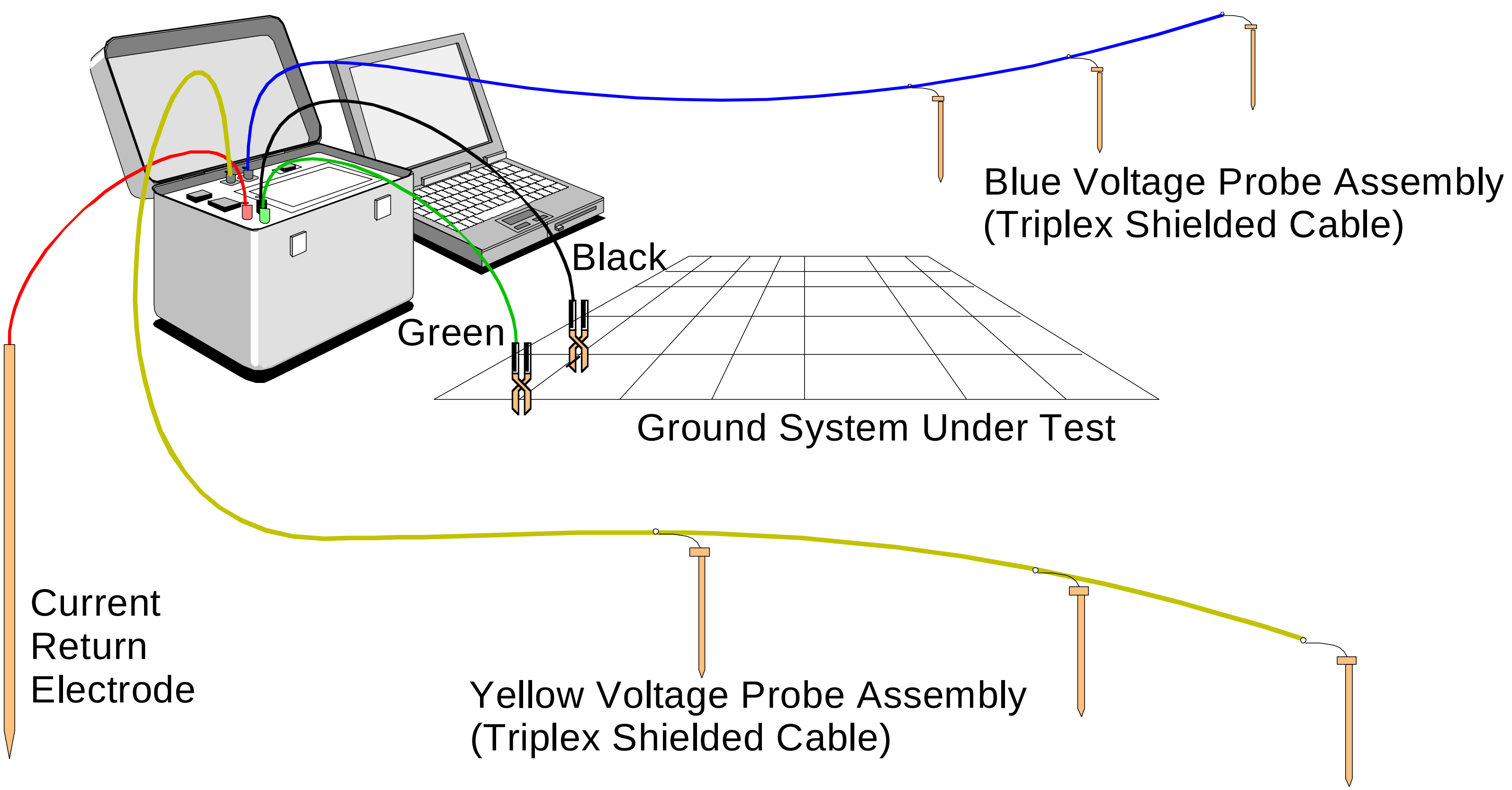
Annex E.3 Computer-based ground meter - Modified fall-of-potential

"The fall-of-potential method is the most popular method of measuring the resistance of ground electrodes and has been widely used for many years. However, there are many variables and situations that can distort test results and greatly reduce the accuracy of these measurements. In recent years, a computer-based ground meter has been developed that can moderate the effect the variables have on test results and improve the accuracy of the measurements."

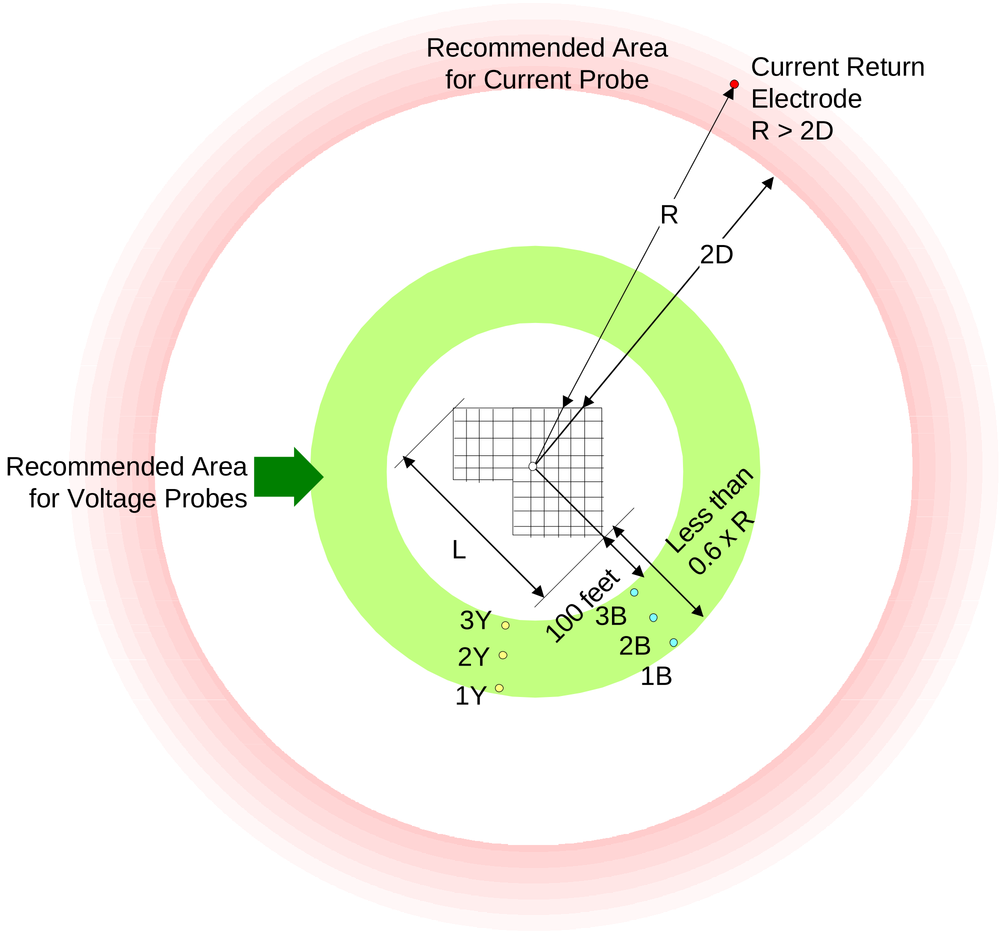
Computer Based Multimeter Method

- Grounding system does not have to be isolated
- Current return distance is minimized
- Large quantity of samples taken
- Data corrected for noise, etc.
- Calibration is performed for every case
- Probe performance is quantified
- Statistical analysis is performed

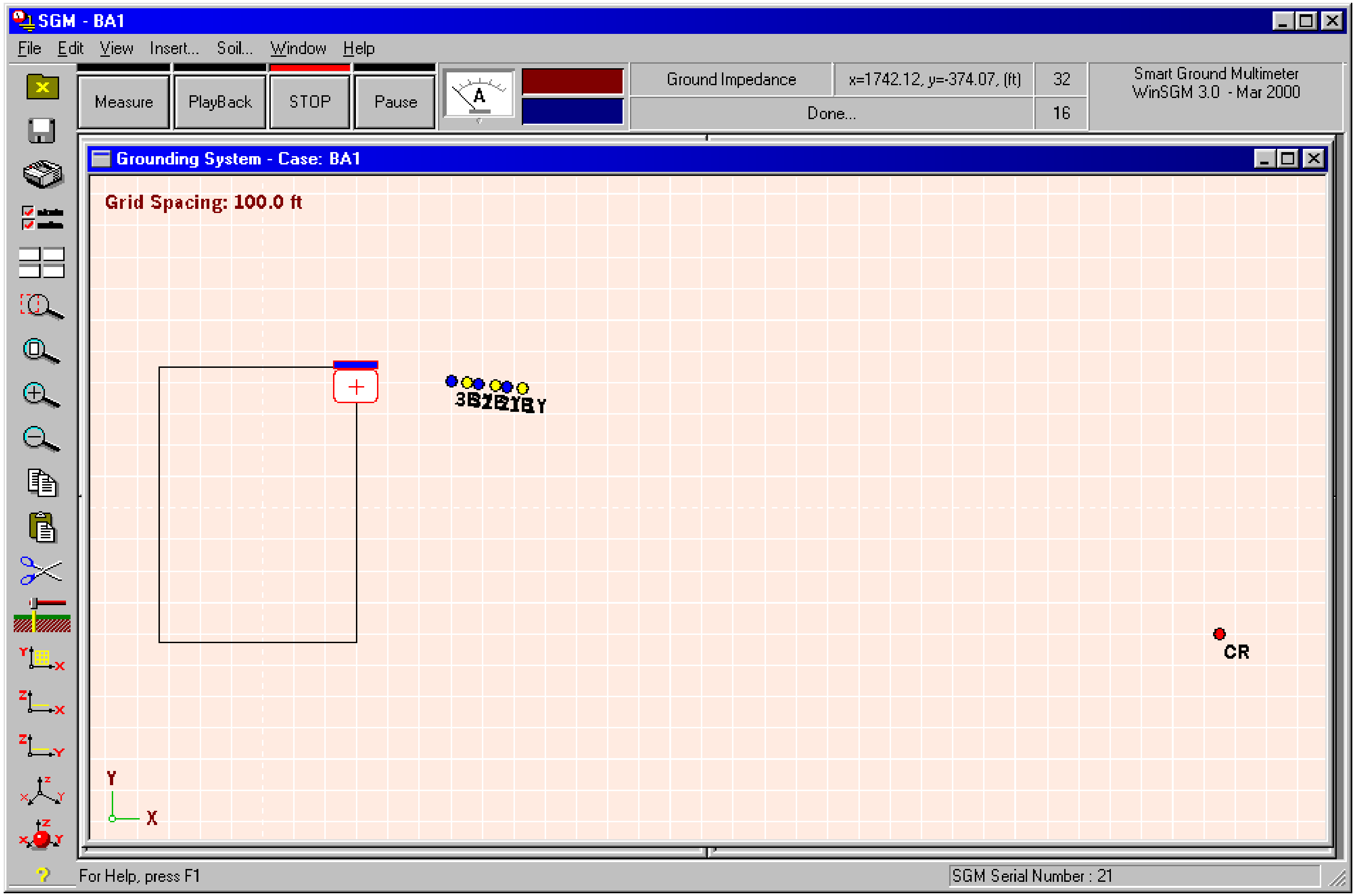
Equipment Set Up



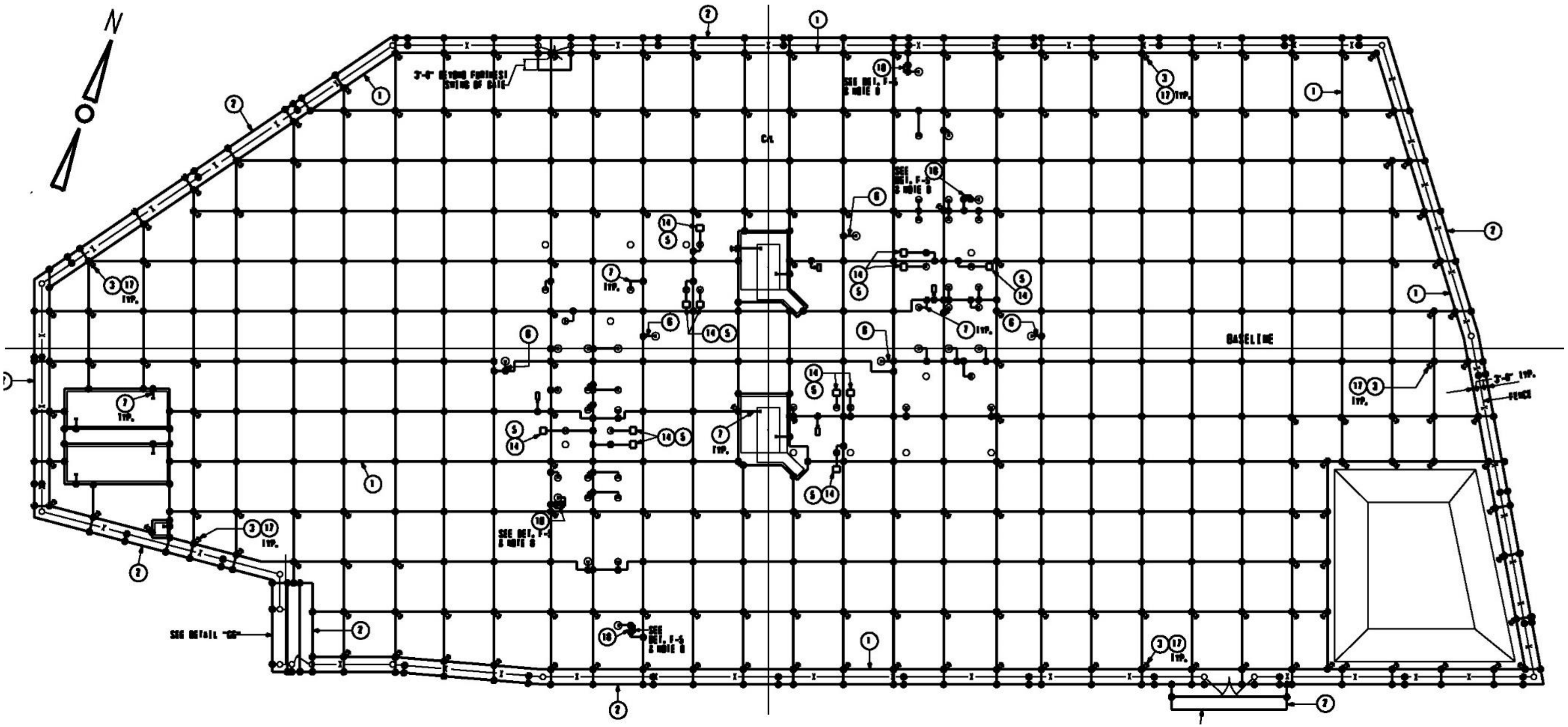
General Probe Placement



Site Specific Grounding Geometry



Site Specific Ground Grid Model



Site Test View

Probe Performance

SGM **Probe Performance Report**

Case: HOHENWALD_SGM-S-X-X-X

Probe	Resistance (Ω)	Soil Resistivity (Ω - m)	Capacitance (pF)	Inductance (mH)	Error (%)	
1Y	57.13	28.3	0.00	0.57	5.71	☐ Remove
2Y	126.97	62.9	0.00	2.09	3.80	☐ Remove
3Y	102.45	50.8	0.00	1.34	3.84	☐ Remove
1B	258.67	128.2	0.01	0.00	1.95	☐ Remove
2B	128.79	63.8	0.00	0.96	3.00	☐ Remove
3B	230.27	114.1	0.00	0.24	2.07	☐ Remove
	Average* 129.12	Average* 64.0				

* NOTE
Maximum value is omitted

Cancel | Proceed

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Data Performance

SGM **Data Acquisition Performance**

Case Name: HOHENWALD_SGM-S-X-X-X

Injected Current: 2.54 Amperes RMS

Prb #	%Valid	%Error	Resistance (Ohms)	Coherence Average-Squared	Quality	
1Y	57.28	6.59	57.1	0.8968	Acceptable	☐ Remove
2Y	55.34	4.51	127.0	0.8890	Good	☐ Remove
3Y	52.75	5.05	102.4	0.8812	Acceptable	☐ Remove
1B	58.90	4.28	258.7	0.8988	Good	☐ Remove
2B	55.66	4.46	128.8	0.8909	Good	☐ Remove
3B	55.02	4.53	230.3	0.8867	Good	☐ Remove

Cancel Proceed

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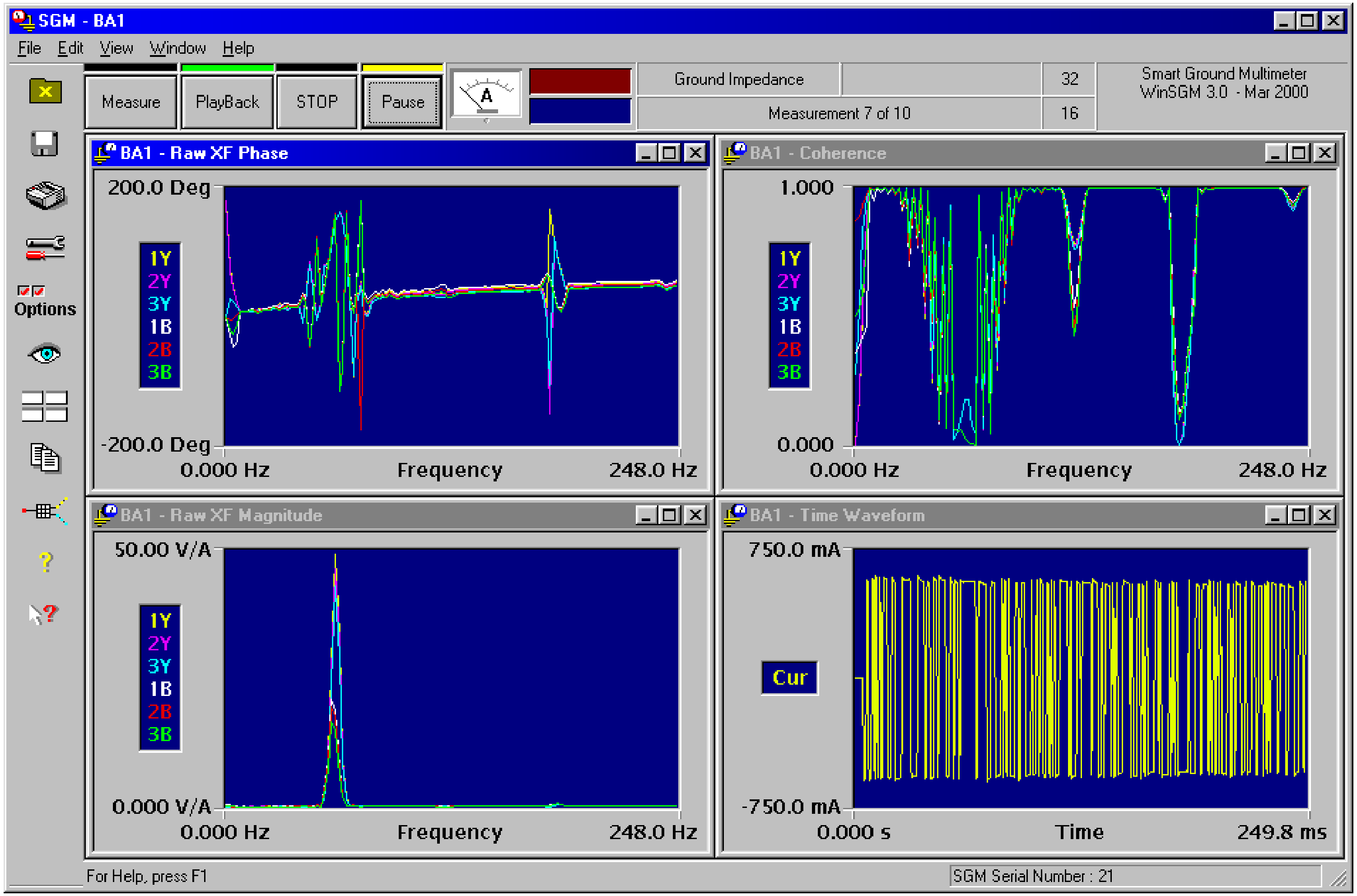
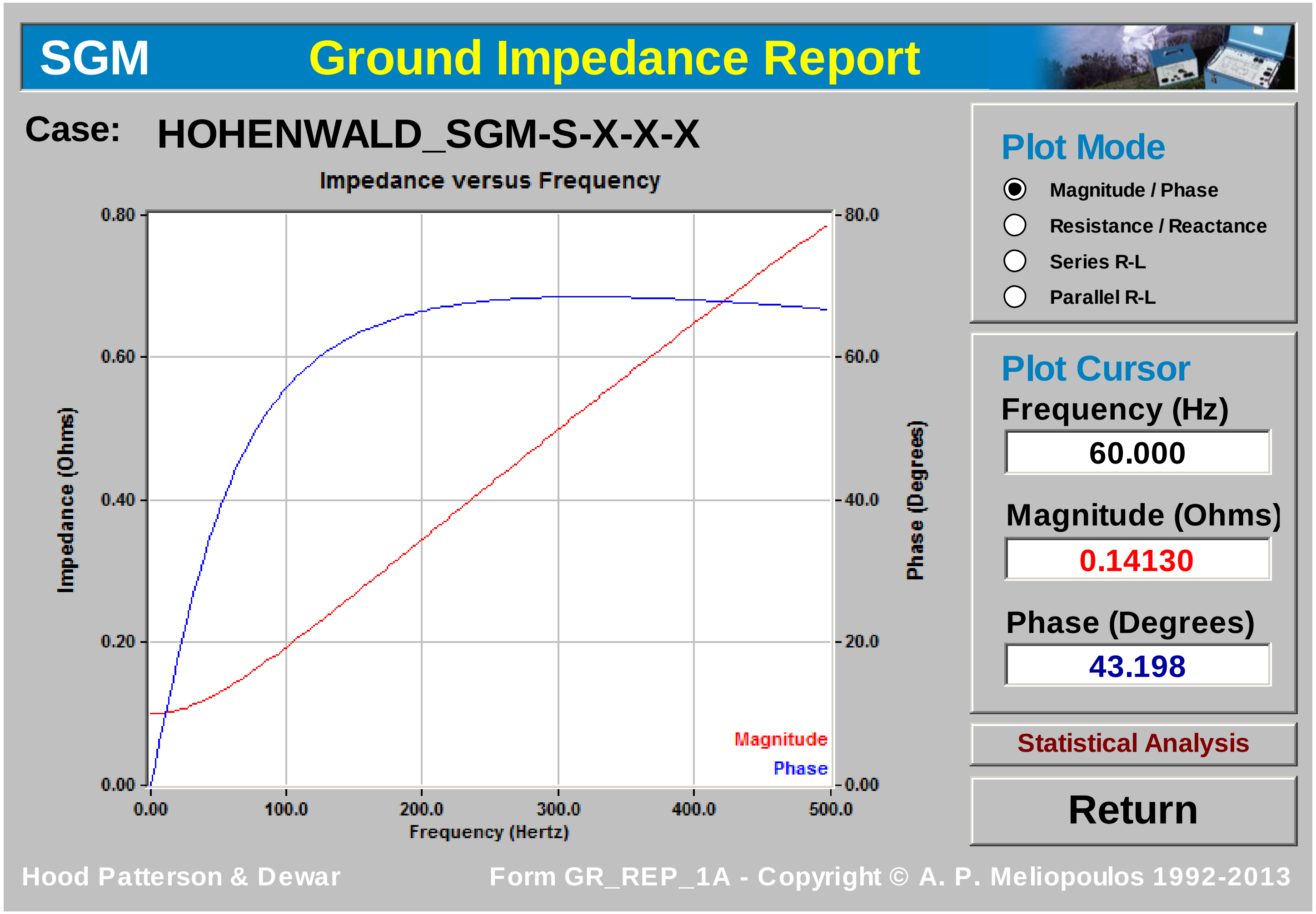
Data Spectrum Analysis



Ground Impedance



Statistical Analysis

SGM Statistical Analysis

Case: HOHENWALD_SGM-S-X-X-X

Return

Error Vs Confidence Level

Conf.%	Error %
0.00	4.0%
100.00	8.0%
100.00	12.0%
100.00	16.0%
100.00	20.0%

Probe Performance Index

1Y	0.04	1B	0.03
2Y	0.02	2B	0.02
3Y	0.03	3B	0.02

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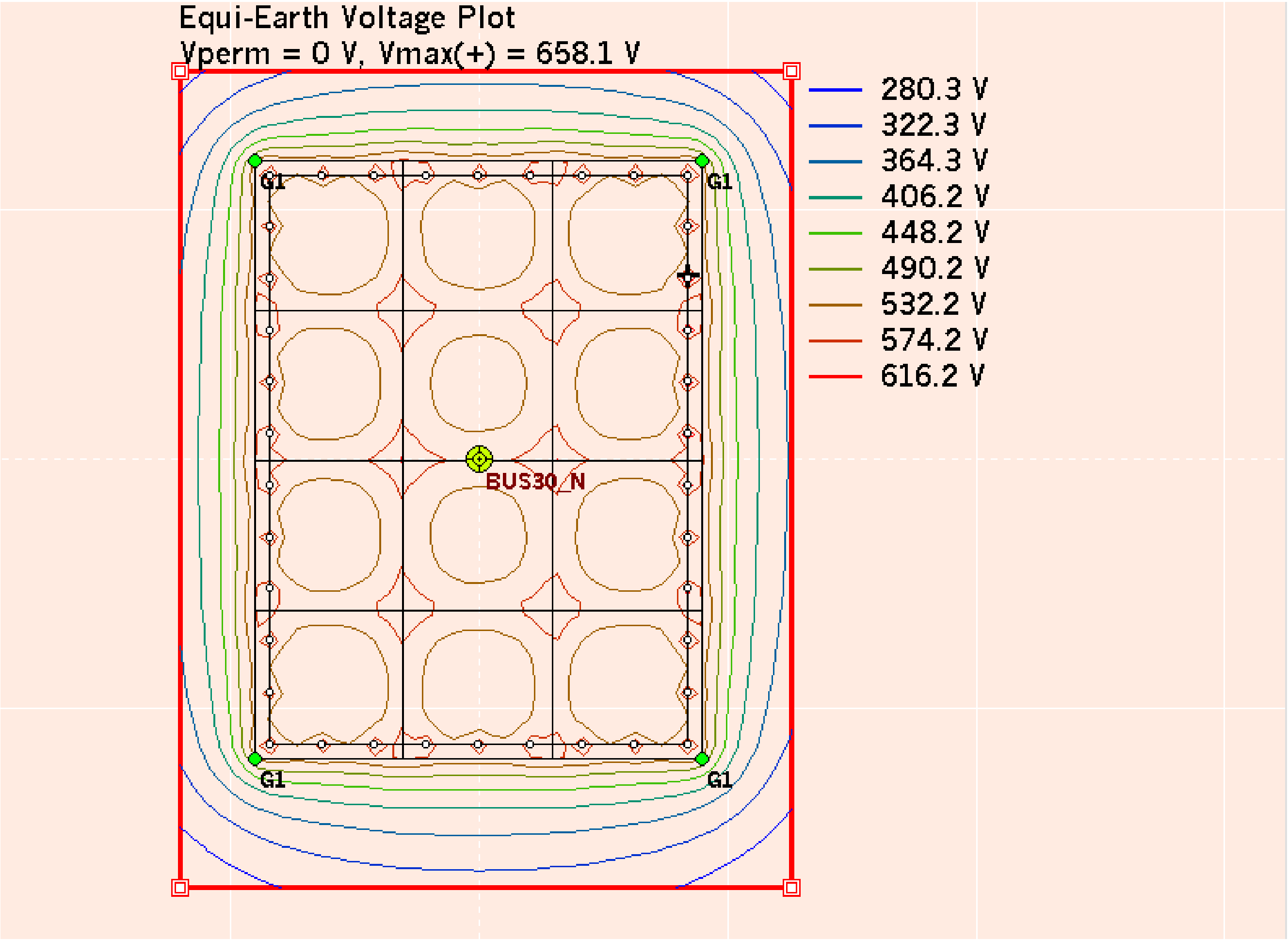
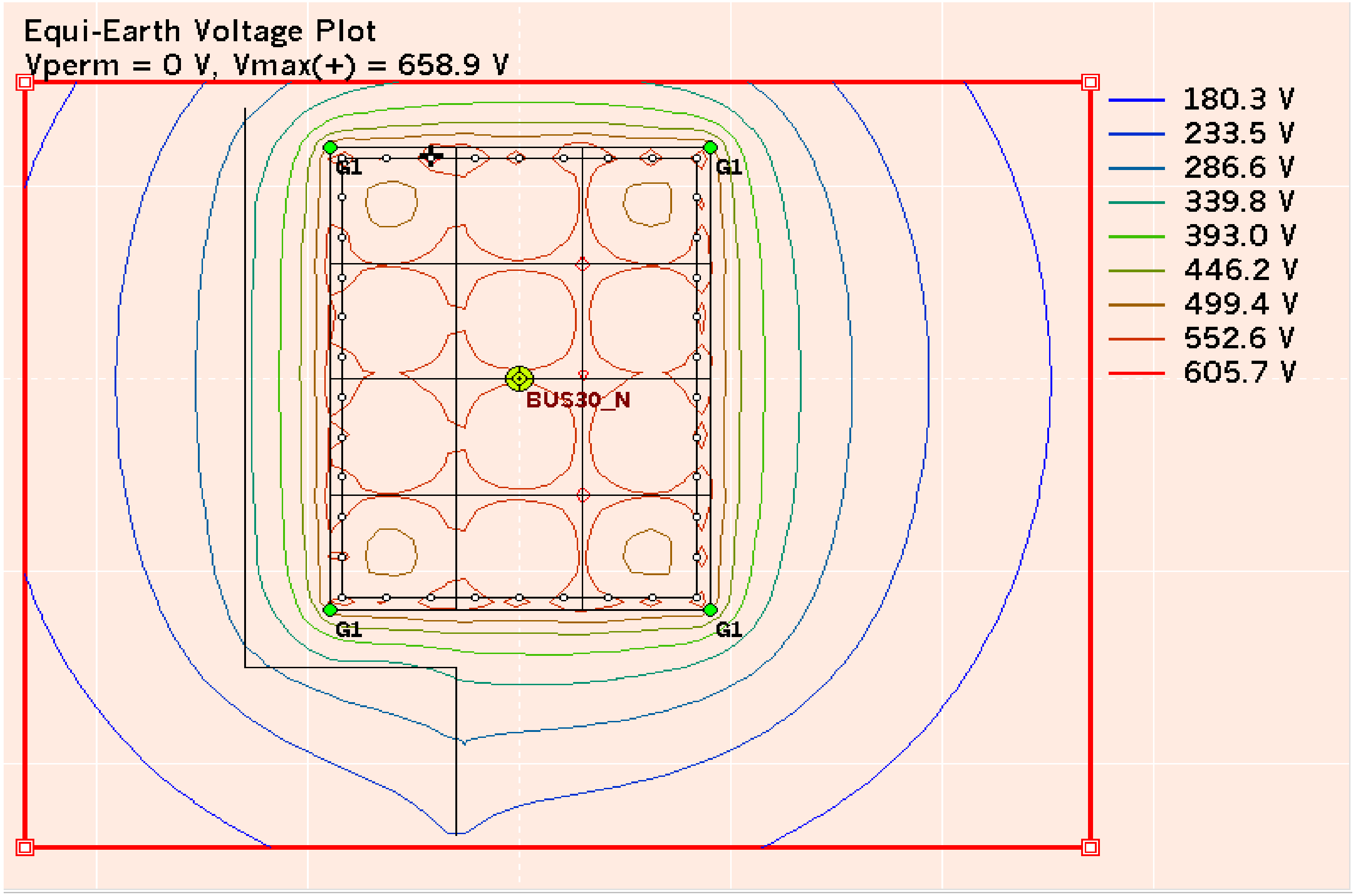
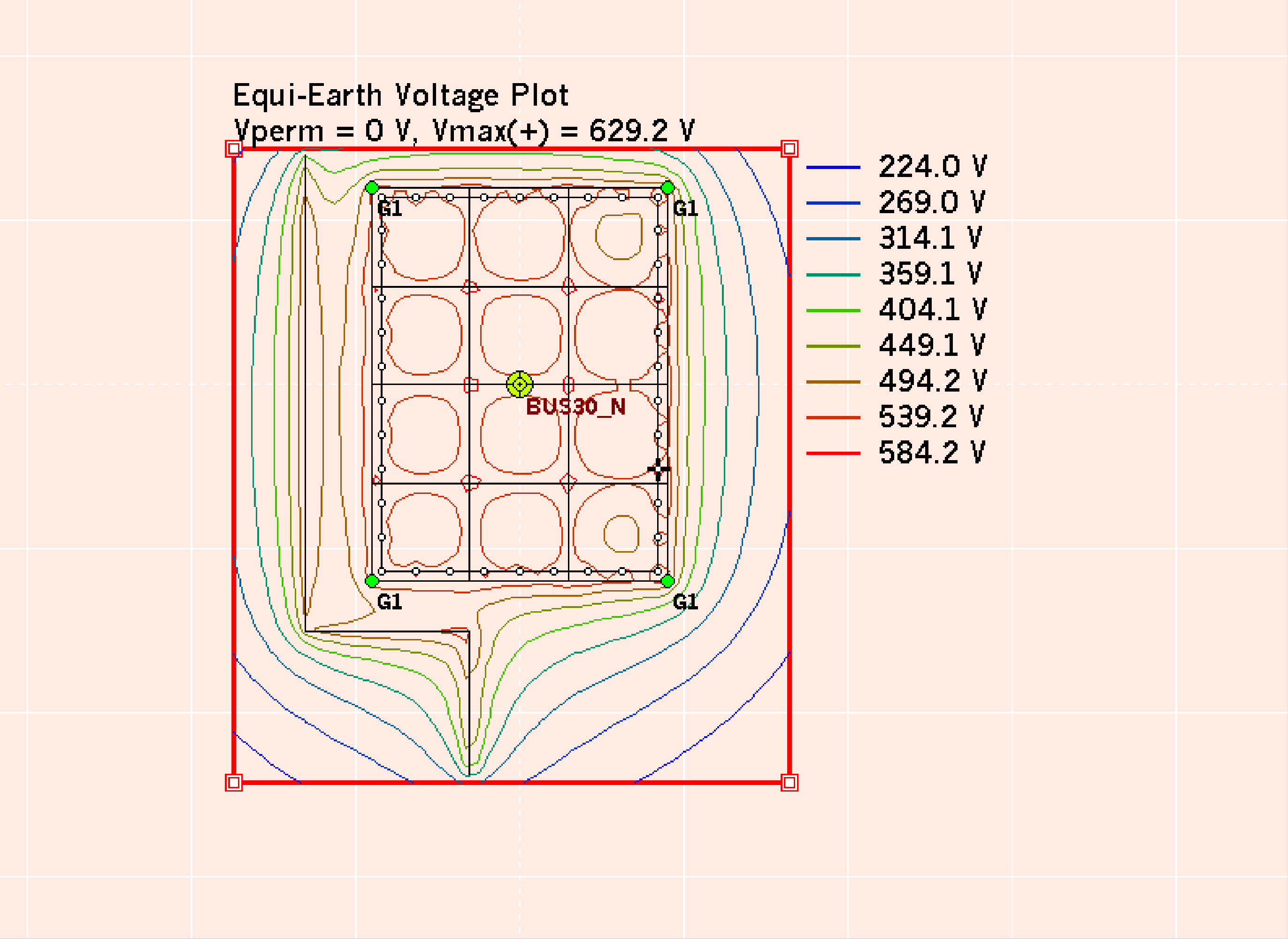
Hypothetical Voltages



Hypothetical Voltages



Hypothetical Voltages



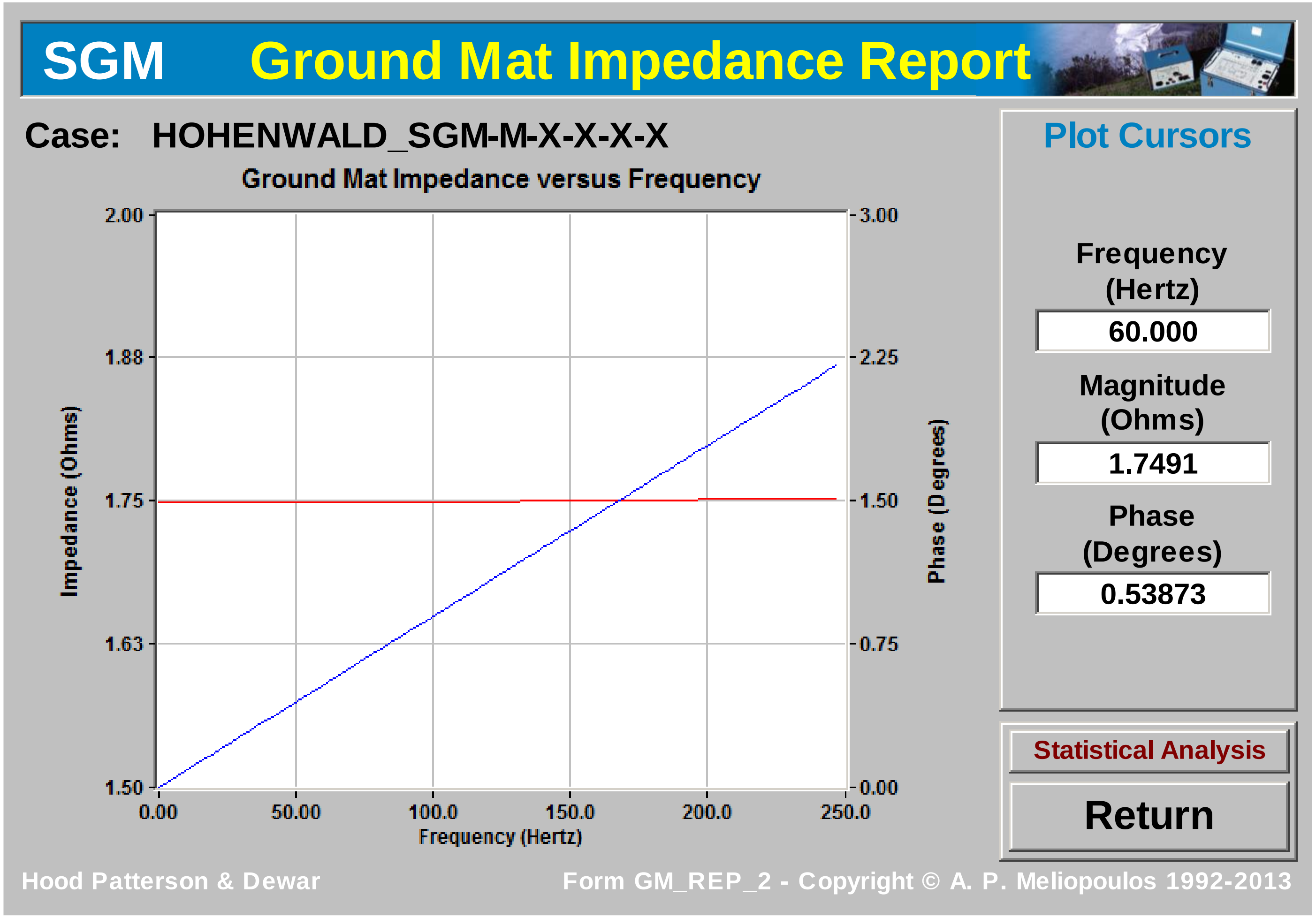
Ground Impedance Problems

- High probe index (poor probe performance)
- High error/low confidence
- Insufficient injected current
- High earth voltage harmonics

Ground Mat Impedance

- What's the difference between the Ground Impedance test and the Ground Mat Impedance test?
- Is it performed differently?
- Can the Fall-Of-Potential method be compared to the Computer Based method?

Ground Mat Impedance Case



Summary

TESTING CHALLENGE	FOP	SGM
Isolated ground grid	Yes	No
Distance for current probes	5-10 times ground grid diagonal	2 times ground grid diagonal
Current electrodes – need sufficient current	Typical test equipment = 5-40mA	2-15A
Voltage electrodes – need low resistance	Probe resistance unknown	Probe resistance quantified & qualified by software
Stray currents	Can influence result - unquantified	Influence removed by software
Reactive component of impedance of large ground grid	Can influence result - unquantified	Influence documented by software
Ground grid shape	Large and/or complex shaped grids require knowledge of "electrical center" for accuracy	Shape is modeled in software
Coupling between test leads	Can influence result - unquantified	Influence documented by software - Probe placement can be corrected
Buried metallic objects	Can influence result – unquantified, presence unknown	Influence documented - Modeling/set up can be corrected
Phase angle measurements – needed for impedance results	Unknown	Measured at 6 locations
Quantity of Data	Minimal	140,000 data samples per test
Frequency spectrum	Fixed or variable to 400Hz	User selected 0-1,000Hz
Statistical Analysis	None	Based on site model
Resulting measured ground grid impedance value	Unquantified	Quantified & Qualified

What to Specify?

Replace

> natural drainage or seepage and without chemical treatment or other artificial means of reducing natural ground resistance.
>
> b. Perform tests by fall-of-potential method according to IEEE 81.

with

Perform tests by method as described in IEEE 81-2012.

Questions?

Thank you