Smart Ground Multi-Meter

Joe Boyles

Boyles Electronics

SGM

- The Smart Ground® Multimeter, or SGM, is a computer controlled multi-function instrument for measuring grounding systems.
- Developed by Dr Sakis Meliopolis with the sponsorship of EPRI.

SGM


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The WinIGS software provides 10 measurement functions:

1. Ground Impedance Measurement 2. Soil Resistivity Measurement 3. Tower Ground Resistance Measurement 4. Touch Voltage Measurement 5. Step Voltage Measurement 6. Ground Mat Impedance Measurement 7. Transfer Voltage Measurement 8. Low Impedance/Continuity Measurement 9. Fall of Potential Method Measurement 10. Oscilloscope Function

1. Ground Impedance Measurement

- The ground impedance measurement function can be applied to any existing grounding system.
- The system under test can be energized or de-energized.
- It measures the ground impedance of the system consisting of all interconnected grounding electrodes as well as nearby grounds connected via shield and neutral wires.

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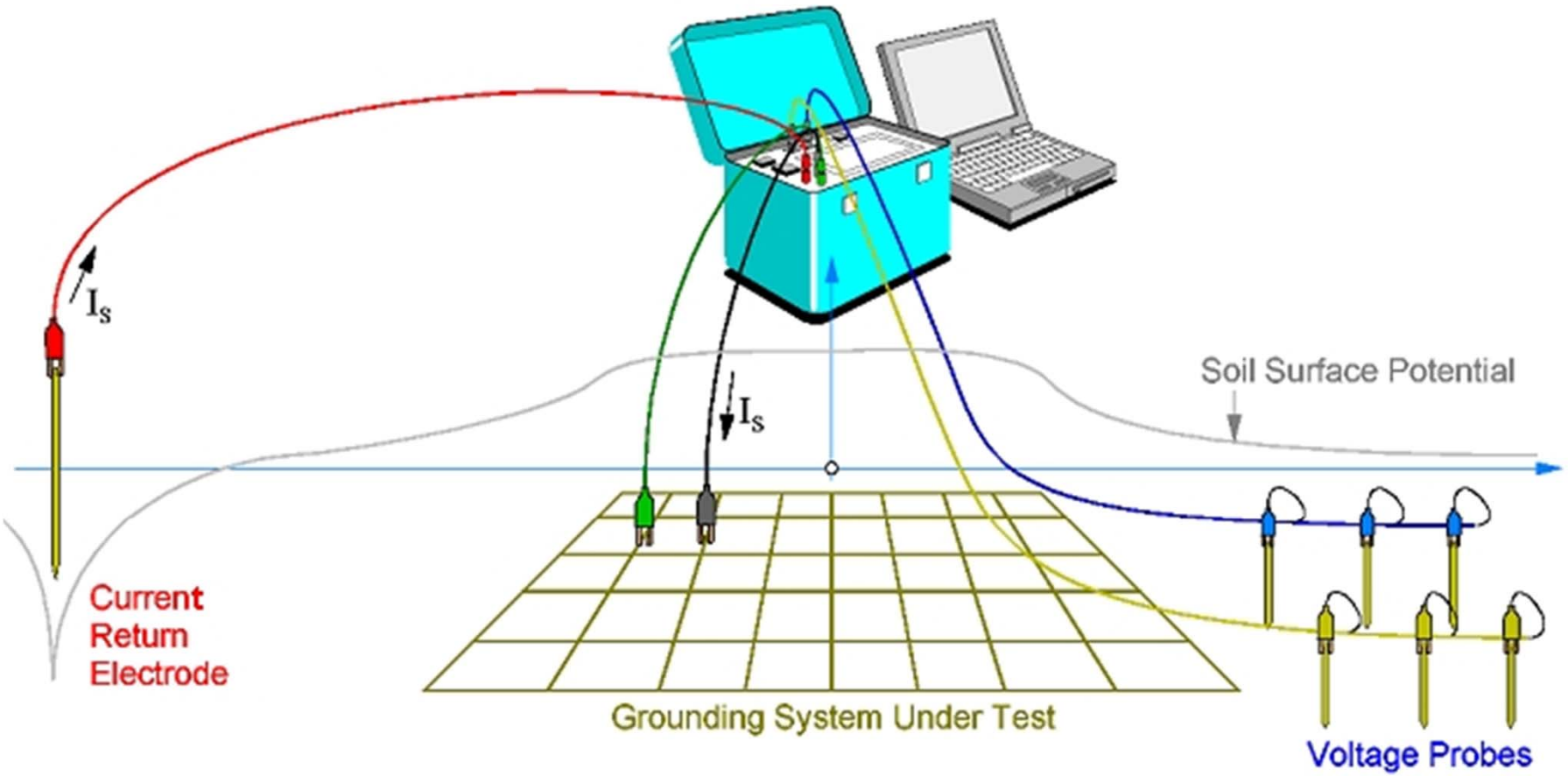
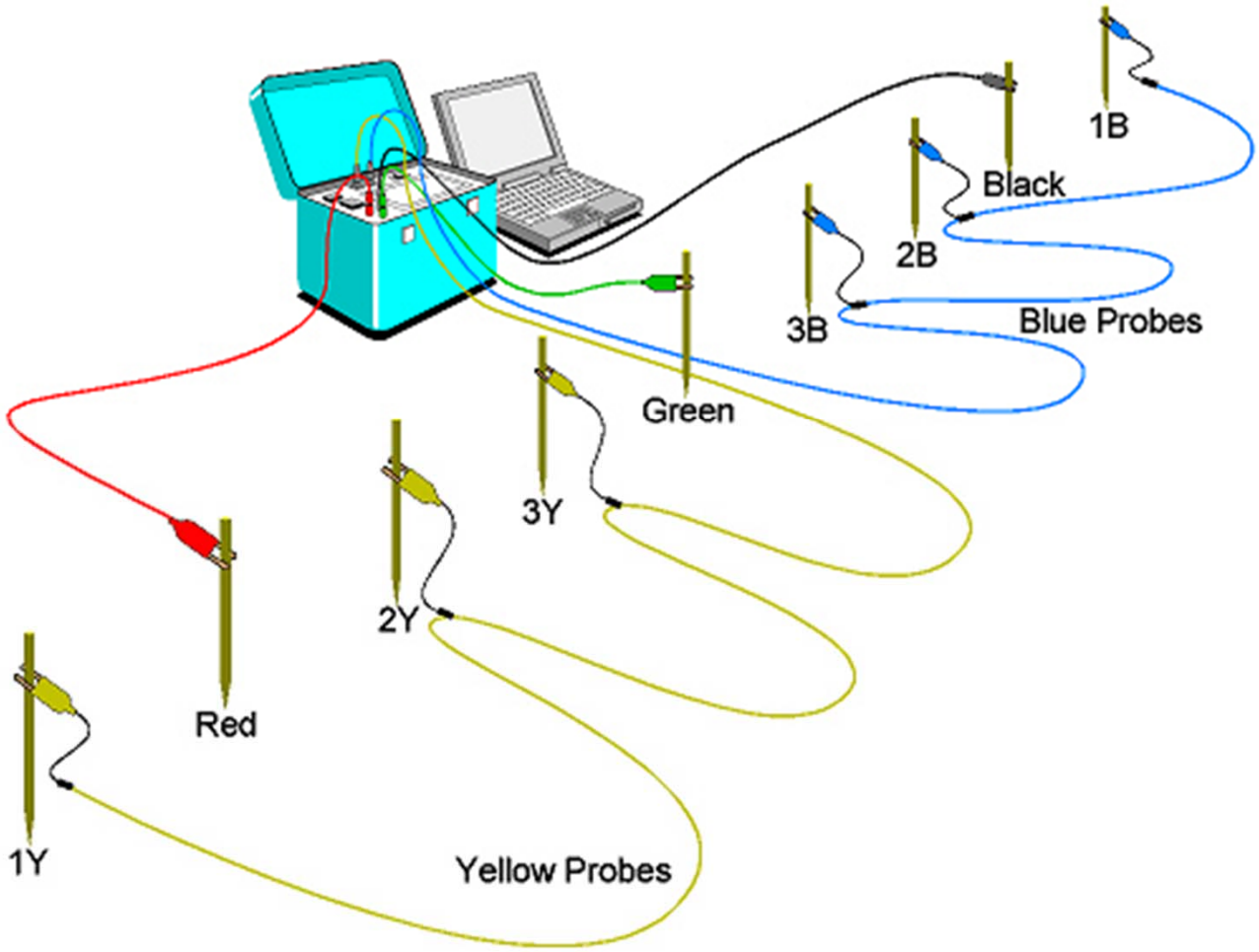
1. Ground Impedance Measurement



2. Soil Resistivity Measurement

- The soil resistivity function is based on an extension of the four-pin Wenner method.
- The SGM takes simultaneous measurements on nine probes uniformly spaced along a line on the soil surface.
- Provides an equivalent 2-Layer resistivity model.

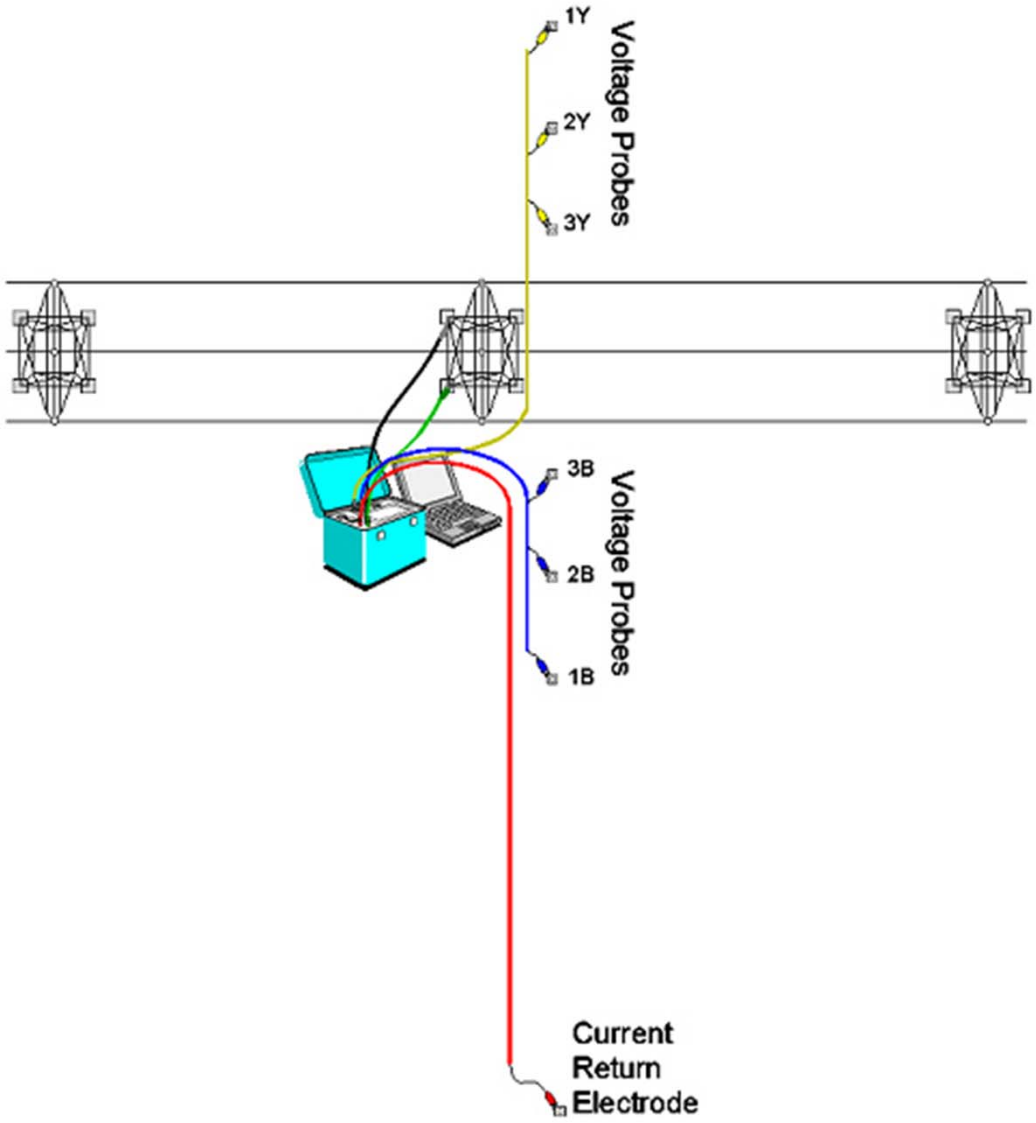
2. Soil Resistivity Measurement



3. Tower Ground Resistance Measurement

- Measures the ground resistance of an energized or de-energized transmission line tower.
- Shield wires may be connected to the tower ground during measurements.

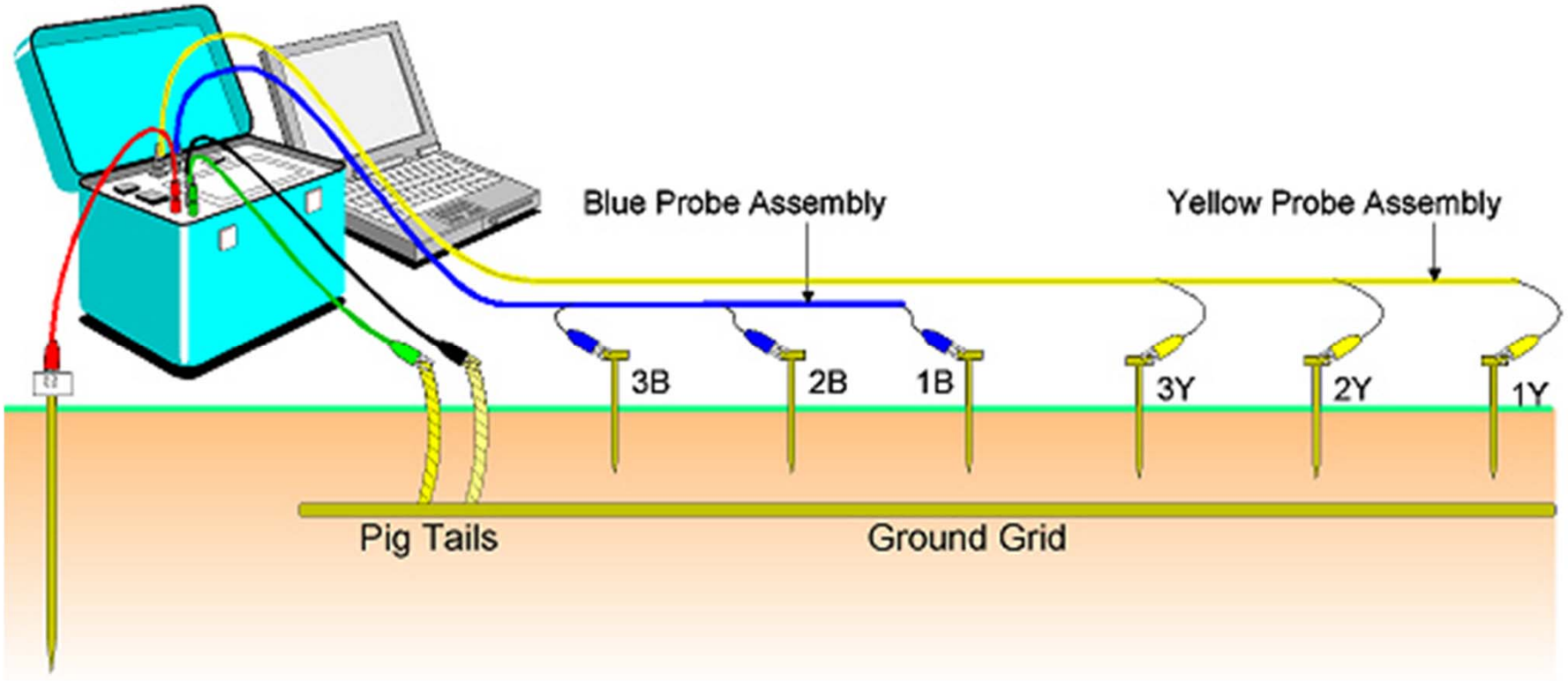
3. Tower Ground Resistance Measurement



4. Touch Voltage Measurement

- Measures the actual touch voltage at a substation as a function of the fault current.
- The measurement is performed at up to six points near a grounding system.

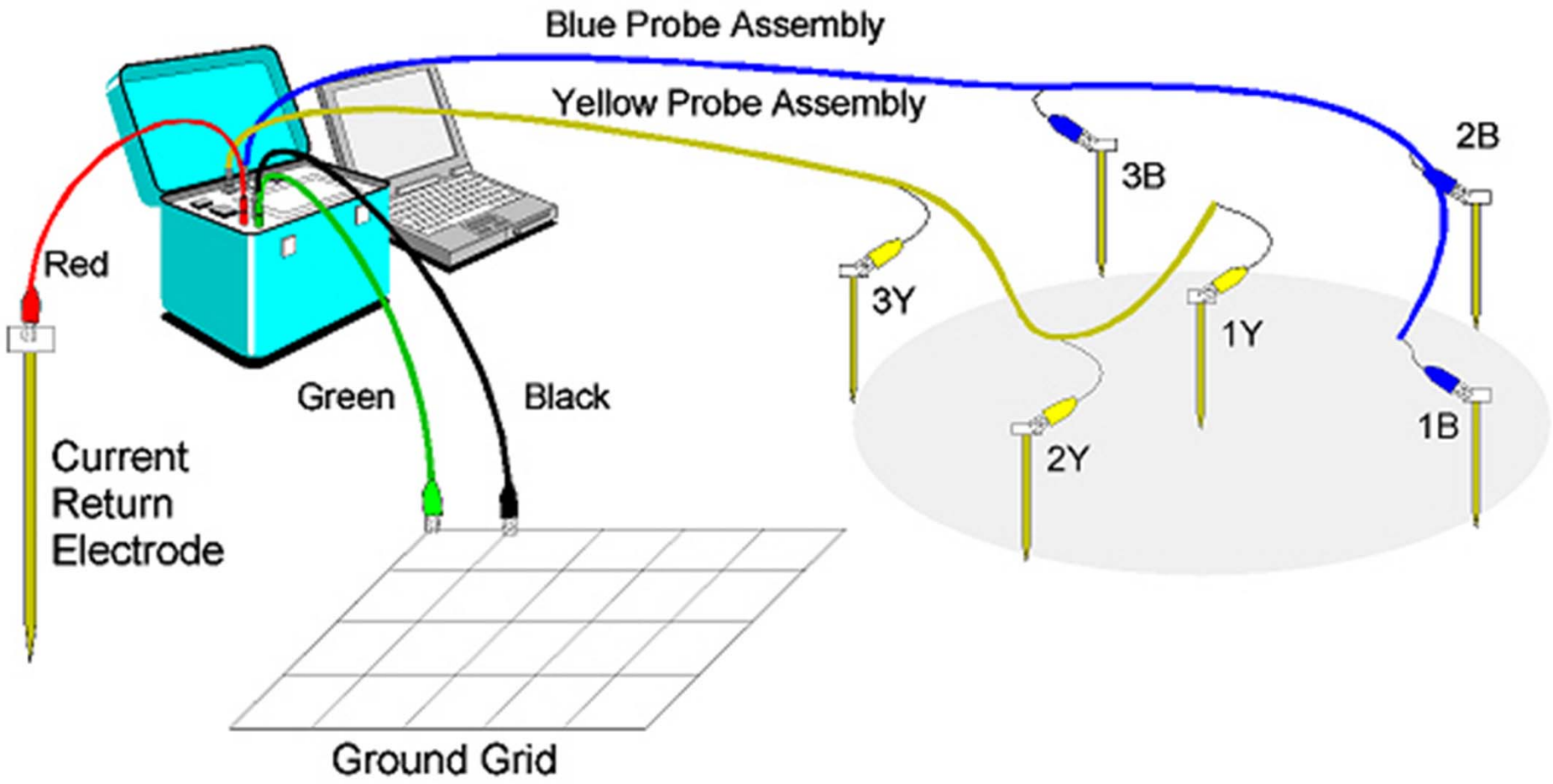
4. Touch Voltage Measurement



5. Step Voltage Measurement

- Measures the actual step voltage at a substation as a function of the fault current.
- The measurement is performed at a user-selected point near a grounding system.

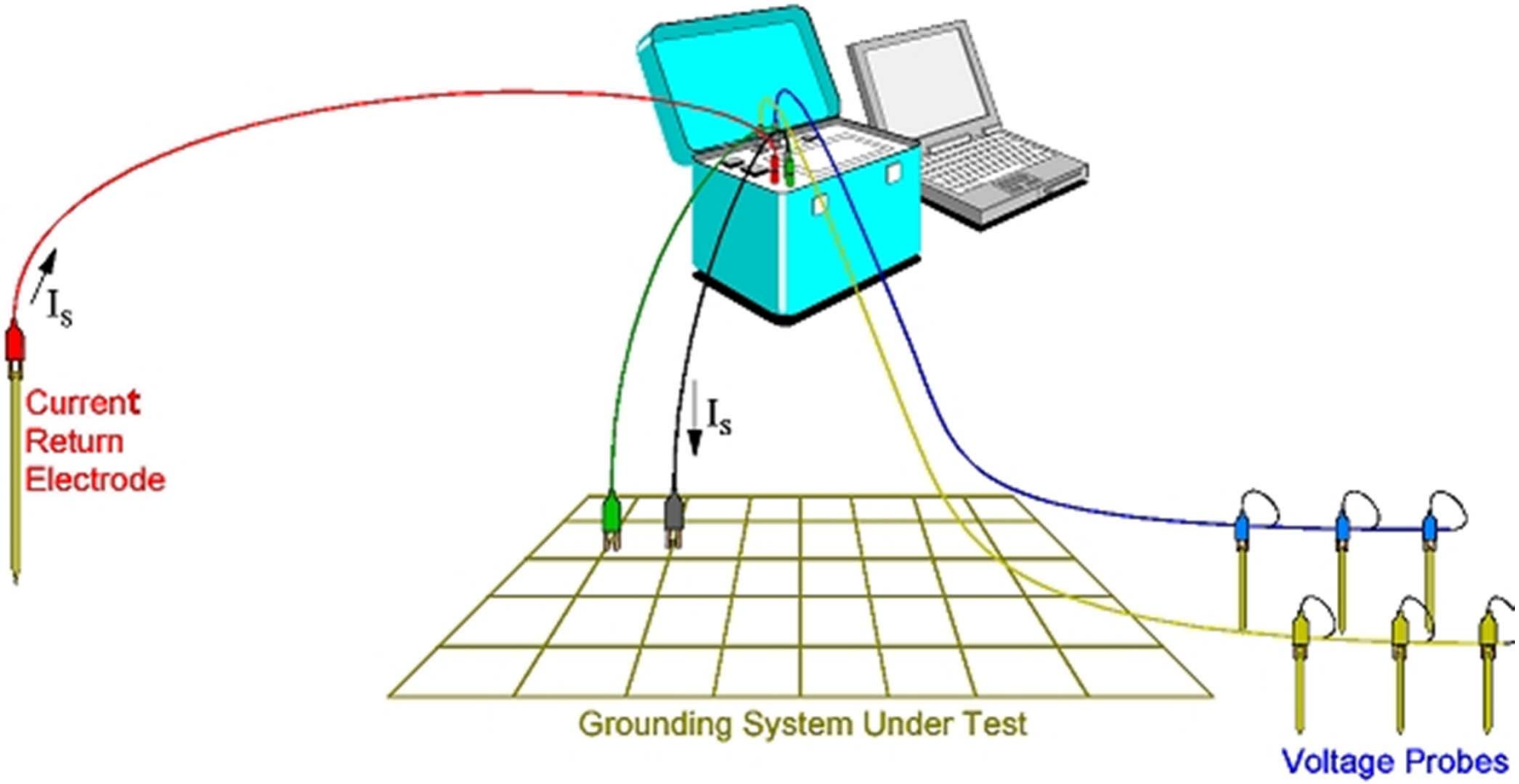
5. Step Voltage Measurement



6. Ground Mat Impedance Measurement

- This function measures the ground mat impedance without disconnecting the shield or neutral wires which may be bonded to the ground mat.
- Setup and connections are similar to the ground impedance measurements.

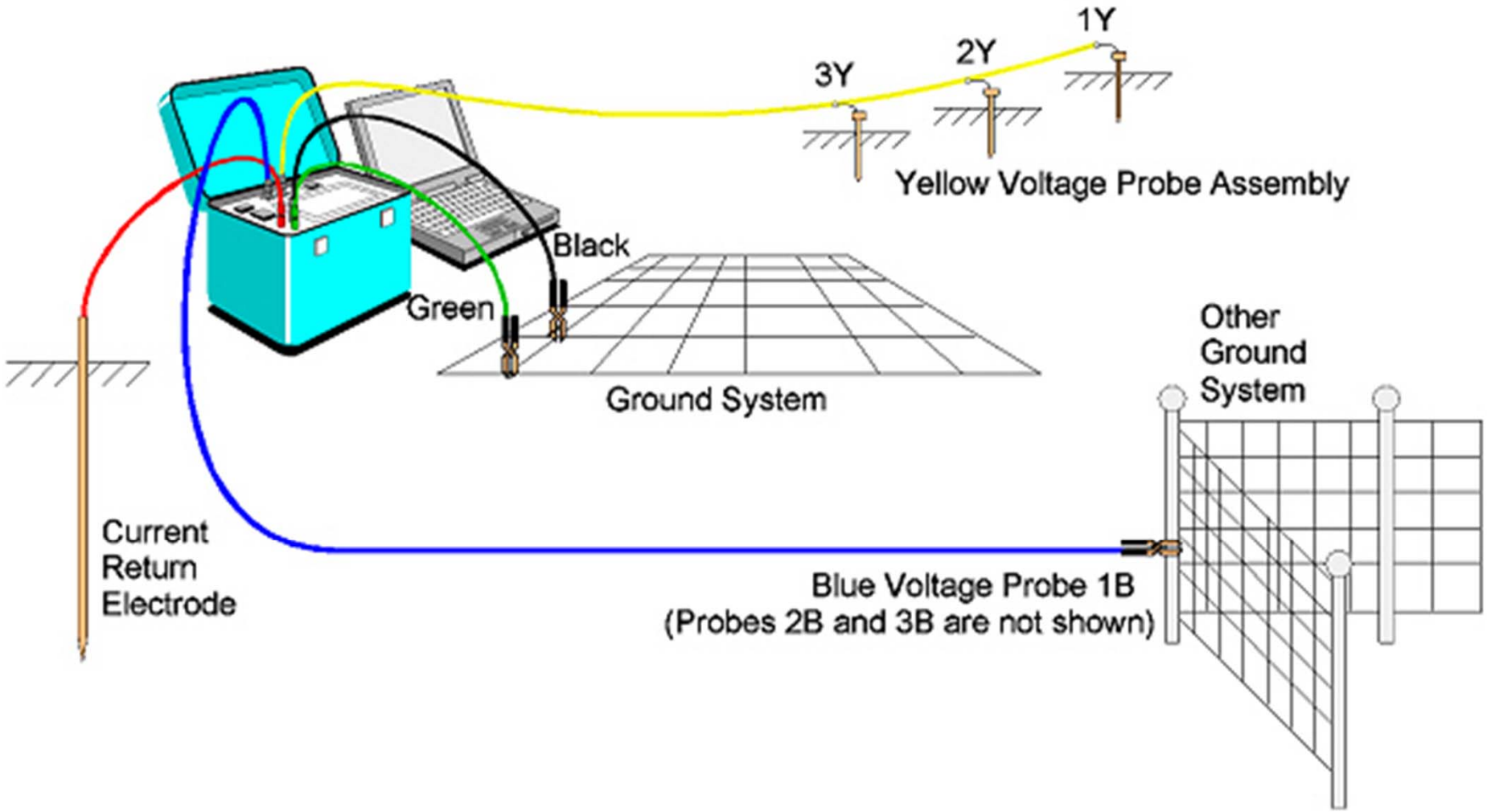
6. Ground Mat Impedance Measurement



7. Transfer Voltage Measurement

- Measures the transfer voltage at a user-selected point or ground. This could be a probe at a specific location such as a proposed CFJ site.
- Measures the voltage as a function of the fault current.

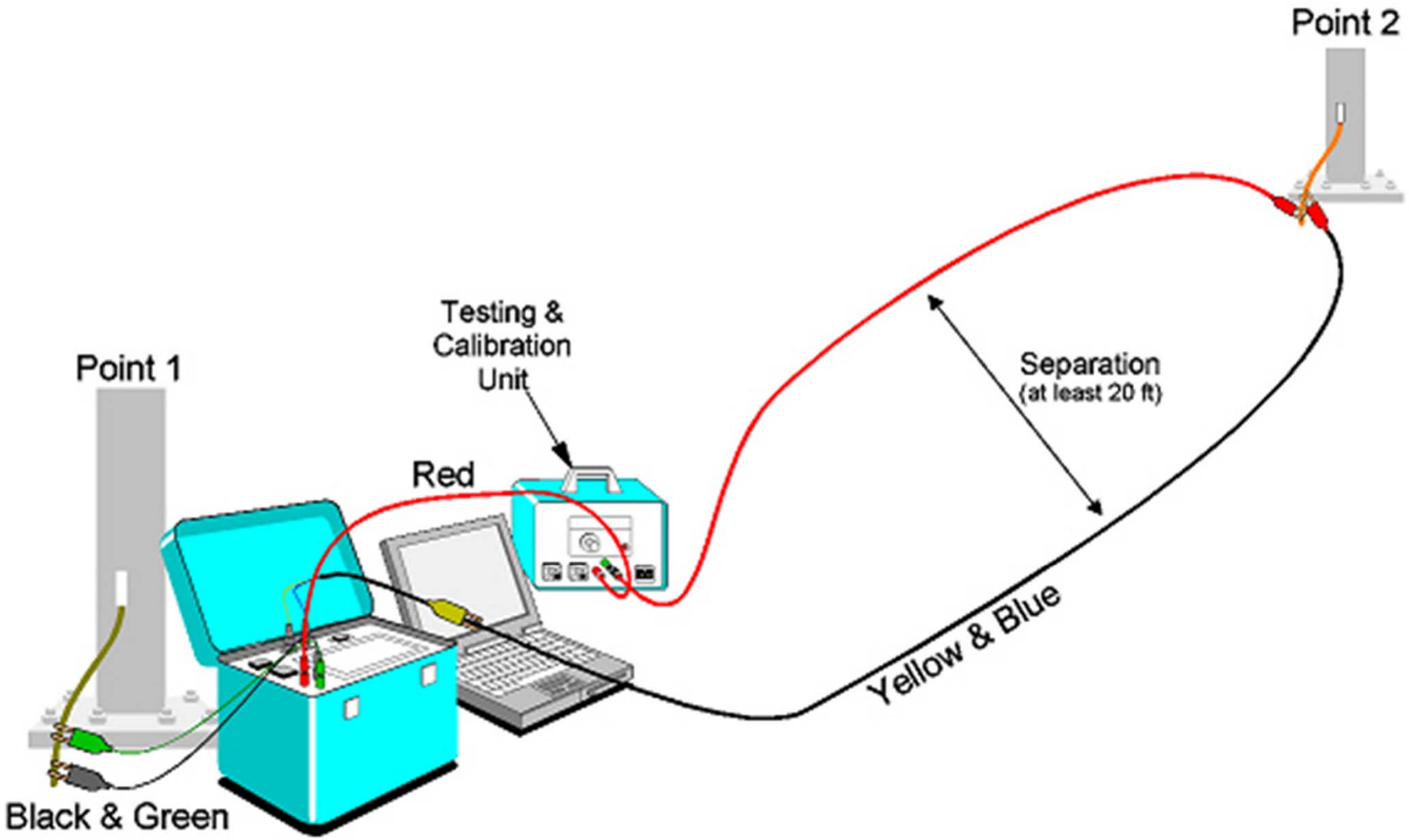
7. Transfer Voltage Measurement



8. Low Impedance/Continuity Measurement

- Measures the impedance between any two user selected points of a grounding system.
- The measurement can be performed on energized grounding systems.
- Accurate results can be obtained even in the presence of substantial external electromagnetic noise.
- Requires a current limiting resistor inserted in series with the red electrode.

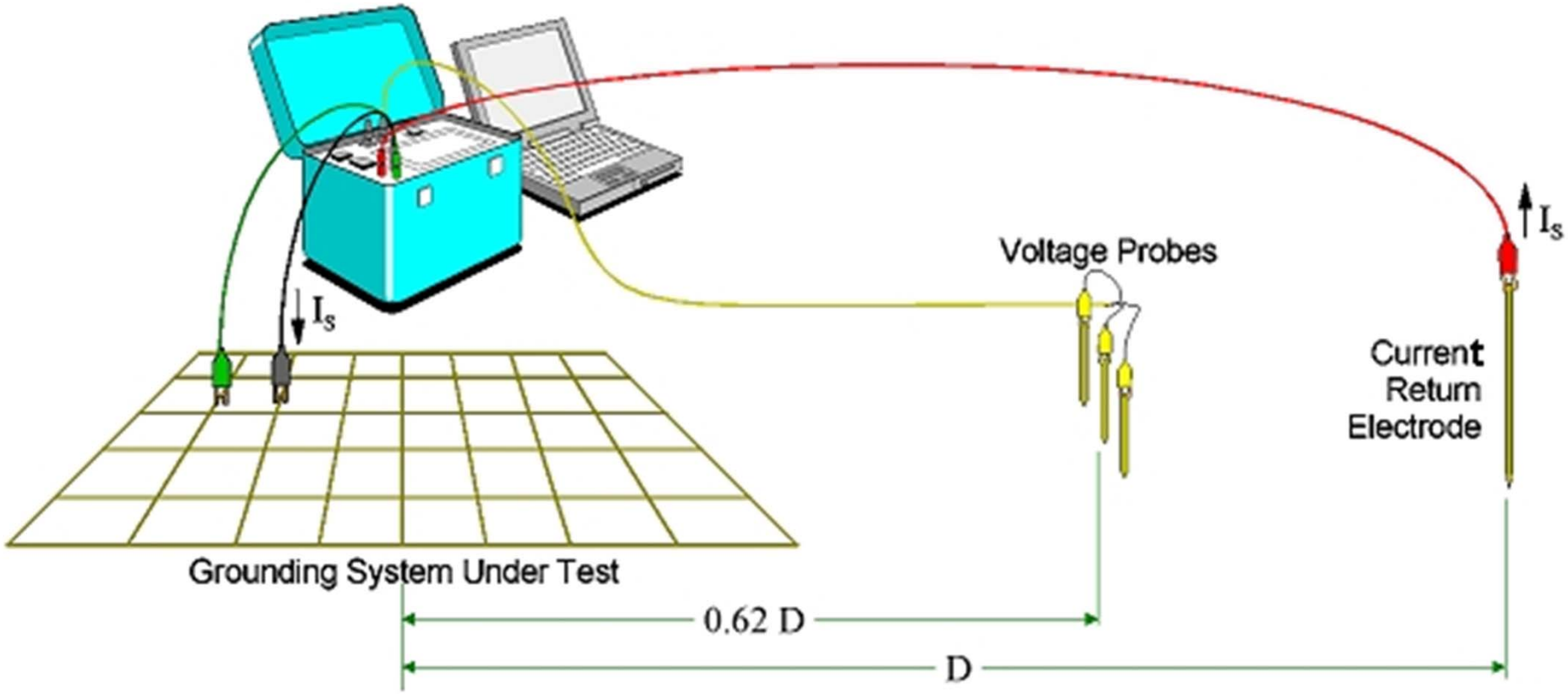
8. Low Impedance/Continuity Measurement



9. Fall of Potential Method Measurement

- Allows using the SGM to perform a ground impedance measurement using the fall-of-potential method.
- The required setup for this function is the standard fall-of-potential probe arrangement.

9. Fall of Potential Method Measurement

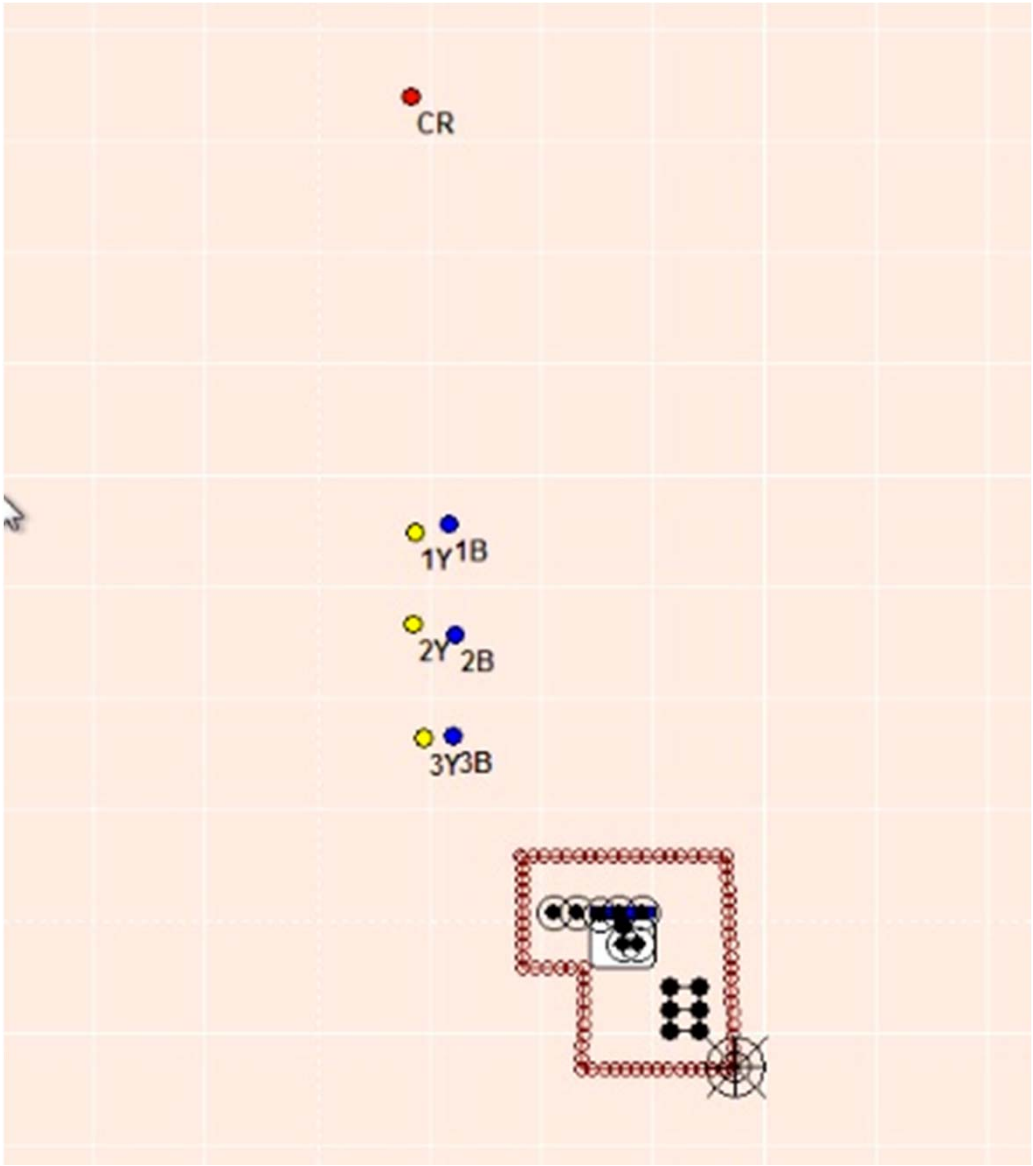


10. Oscilloscope Function

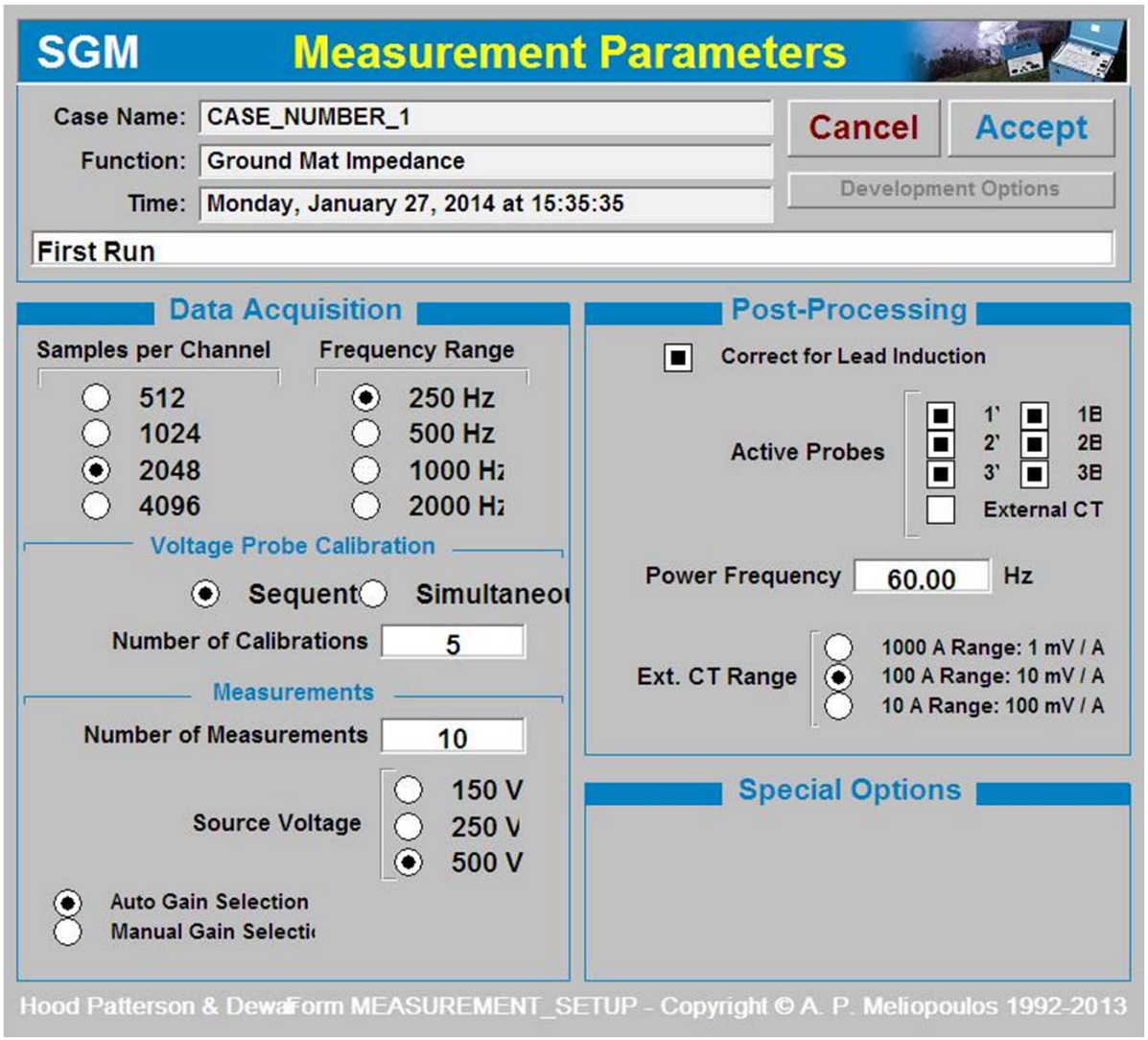
- Allows the SGM to be used as a general purpose six channel waveform data acquisition system.

6. Ground Mat Impedance Measurement

- Probably the single most powerful use of the SGM.
  - Takes advantage of the fact that the impedance of the earth is predominately resistive with virtually no reactive component.
  - The program uses this fact to differentiate between the current that flows through the earth and that which flows through metalic components.
  - The current through the Current Return probe must be minimally 2.0 Amps. Sometimes hard to accomplish.


CR
1Y
1B
2Y
2B
3Y
3B

6. Ground Mat Impedance Measurement



SGM Set Probes Using GPS

Change Format | Cancel | OK

	Latitude Decimal Degrees	Longitude Decimal Degrees	Distance from SGM (◉ Fee ○ Meters)
SGM	35.24834000	-81.03308000	Err=-46.8
Reference	35.24811000	-81.03289000	101.3
Update Drawing → Current Return	Update from Drawing ↓ 35.25023000	-81.03344000	698.6
Probe 1Y	35.24934000	-81.03359000	395.6
Probe 2Y	35.24911000	-81.03362000	324.1
Probe 3Y	35.24883000	-81.03362000	240.8
Probe 1B	35.24935000	-81.03349000	388.6
Probe 2B	35.24908000	-81.03350000	297.9
Probe 3B	35.24883000	-81.03353000	223.7

Hood Patterson & Dewar Form GPS_COORD_D -

SGM Probe Performance Report

Case: CASE_NUMBER_1

Probe	Resistance (Ω)	Soil Resistivity (Ω - m)	Capacitance (pF)	Inductance (mH)	Error (%)	
1Y	184.31	91.4	0.00	3.00	2.27	☐ Remove
2Y	173.26	85.9	0.00	3.43	2.53	☐ Remove
3Y	129.20	64.0	0.00	4.33	6.42	☐ Remove
1B	157.67	78.1	0.00	0.20	1.38	☐ Remove
2B	476.05	236.0	0.03	0.00	1.35	☐ Remove
3B	384.51	190.6	0.01	0.00	3.70	☐ Remove
	Average* 205.79	Average* 102.0	* NOTE Maximum value is omitted			

Cancel Proceed

Hood Patterson & Dewar

SGM Data Acquisition Performance

Case Name: CASE_NUMBER_1

Injected Current: 8.00 Amperes RMS

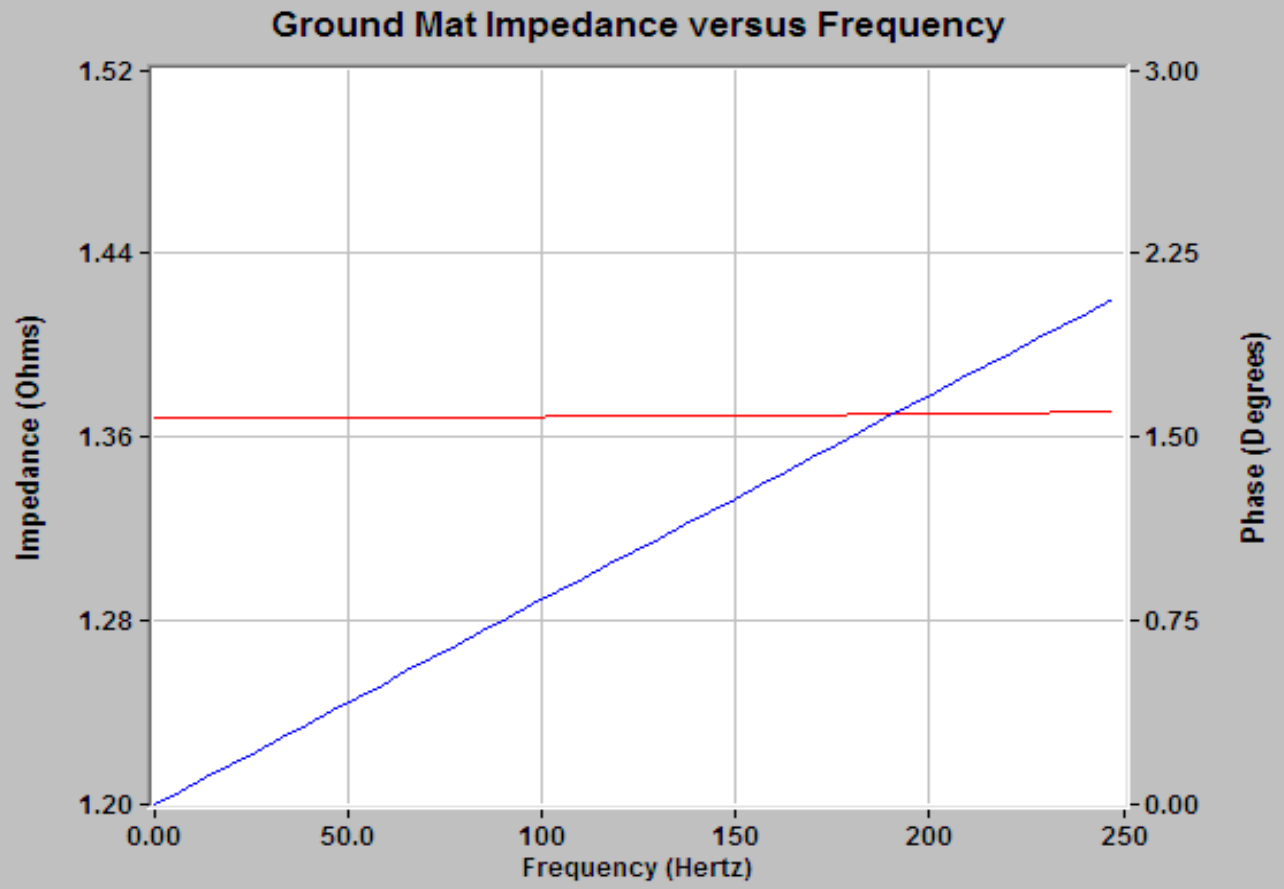
Prb #	%Valid	%Error	Resistance (Ohms)	Coherence Average-Squared	Quality	
1Y	80.77	2.45	184.3	0.9971	Very Good	☐ Remov
2Y	76.92	2.57	173.3	0.9954	Very Good	☐ Remov
3Y	75.64	2.70	129.2	0.9934	Very Good	☐ Remov
1B	80.77	2.10	157.7	0.9973	Very Good	☐ Remov
2B	78.21	2.22	476.0	0.9961	Very Good	☐ Remov
3B	75.64	2.45	384.5	0.9938	Very Good	☐ Remov

Cancel Proceed

Hood Patterson & Dewar

SGM Ground Mat Impedance Report

Case: CASE_NUMBER_1



Plot Cursors

Frequency (Hertz)

60.00

Magnitude (Ohms)

1.369

Phase (Degrees)

0.5028

Statistical Analysis

Return

SGM Statistical Analysis

Case: CASE_NUMBER_1

Return

Error Vs Confidence Level

Conf.%	Error %
0.00	4.0%
0.00	8.0%
7.25	12.0%
99.99	16.0%
100.00	20.0%

Probe Performance Index

1Y	0.12	1B	0.09
2Y	0.11	2B	0.07
3Y	0.05	3B	0.03

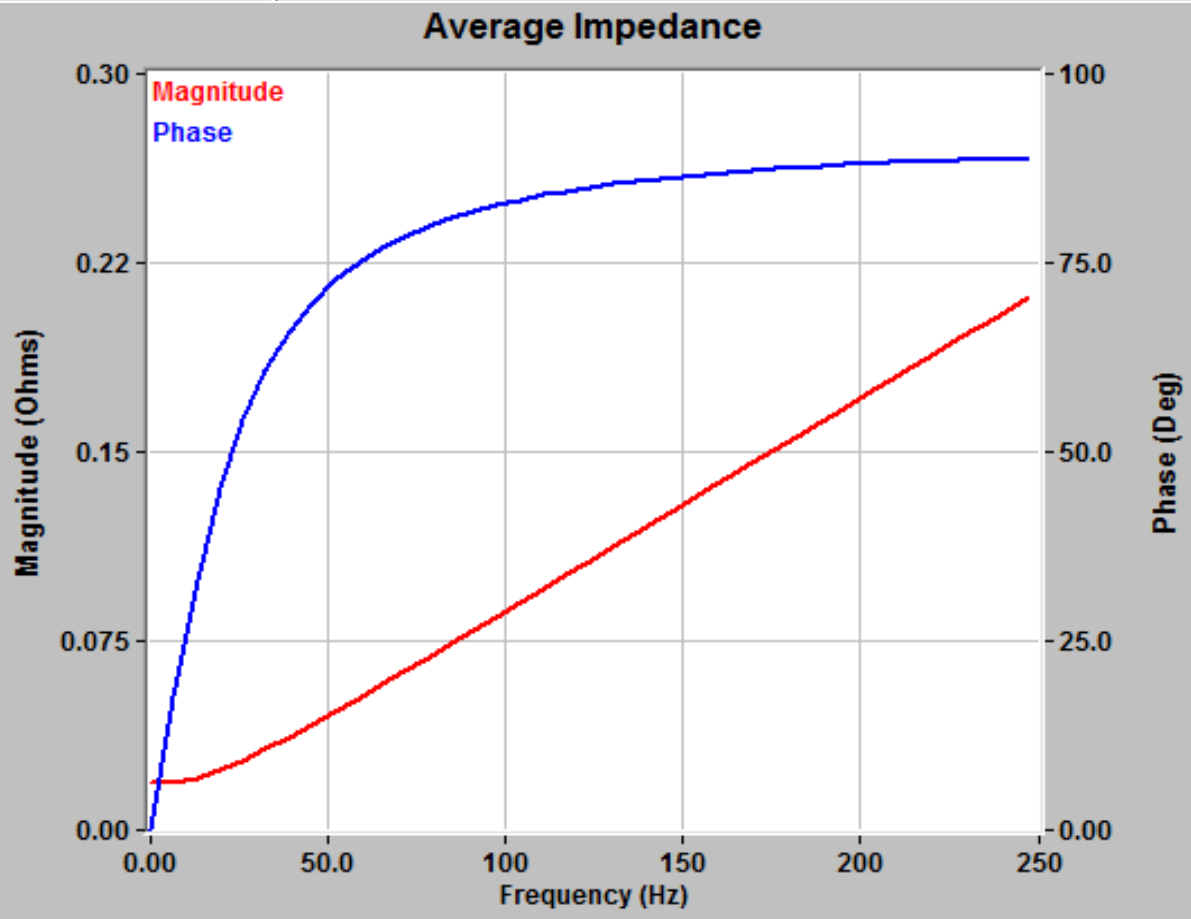
8. Low Impedance/Continuity Measurement

- For sites where the continuity or integrity of the ground grid is in question.
- Provides impedance and phase angle of the connection point-to-point.
- Use one spot as the anchor point and move the other test leads to any above-ground point that needs testing.

SGM Impedance Report

Close

Case Name	Case_1 _PTP	Time	11/12/2013 08:08
Description	Measure between yards.		



Cursor Values

Frequency
60.00 Hz

Impedance
0.05347 Ohms

Phase
75.39 Degrees

Resistance
0.01349 Ohms

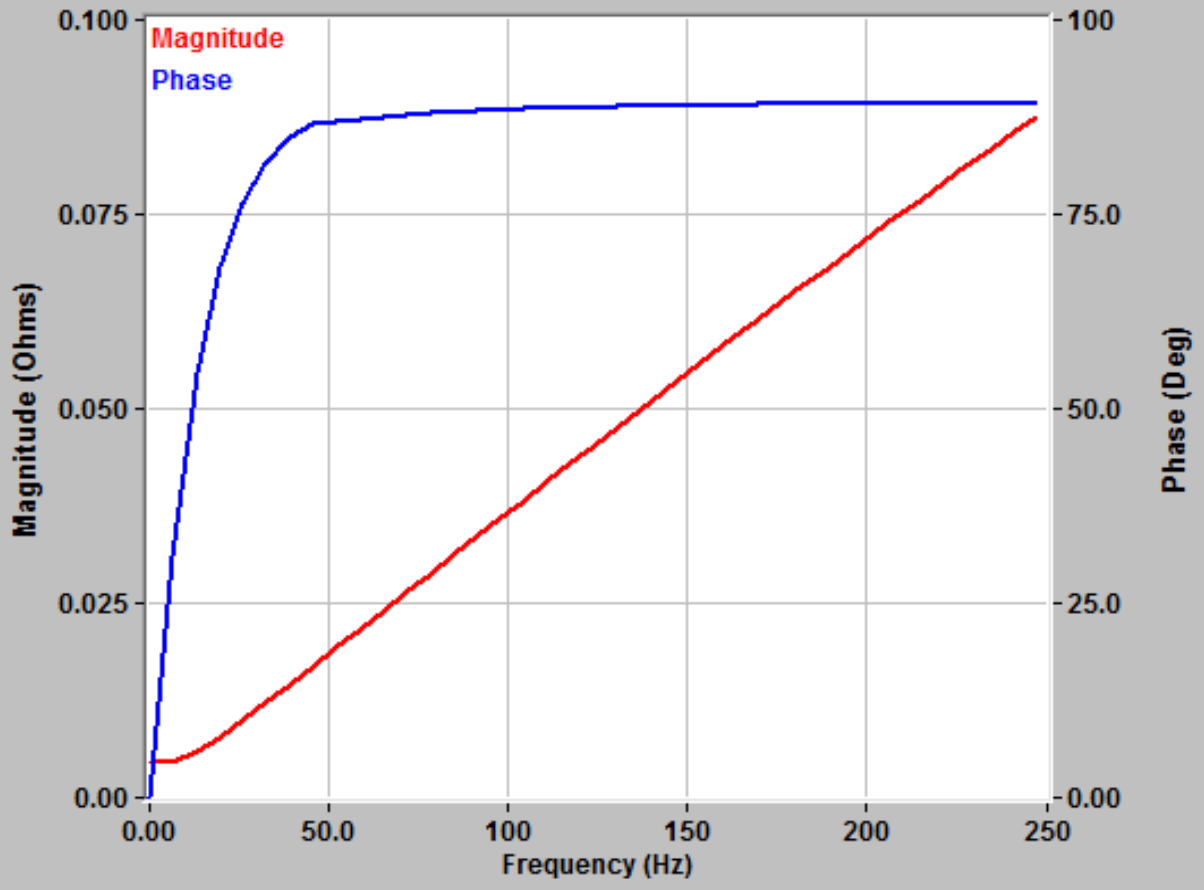
Reactance
0.05174 Ohms

Inductance
0.1372 mH

SGM Impedance Report

Close

Case Name	Case 1 _PTP	Time	11/12/2013 08:42
Description	From Common point 4 to 9		



Cursor Values

Frequency 60.00 Hz

Impedance 0.02217 Ohms

Phase 87.41 Degrees

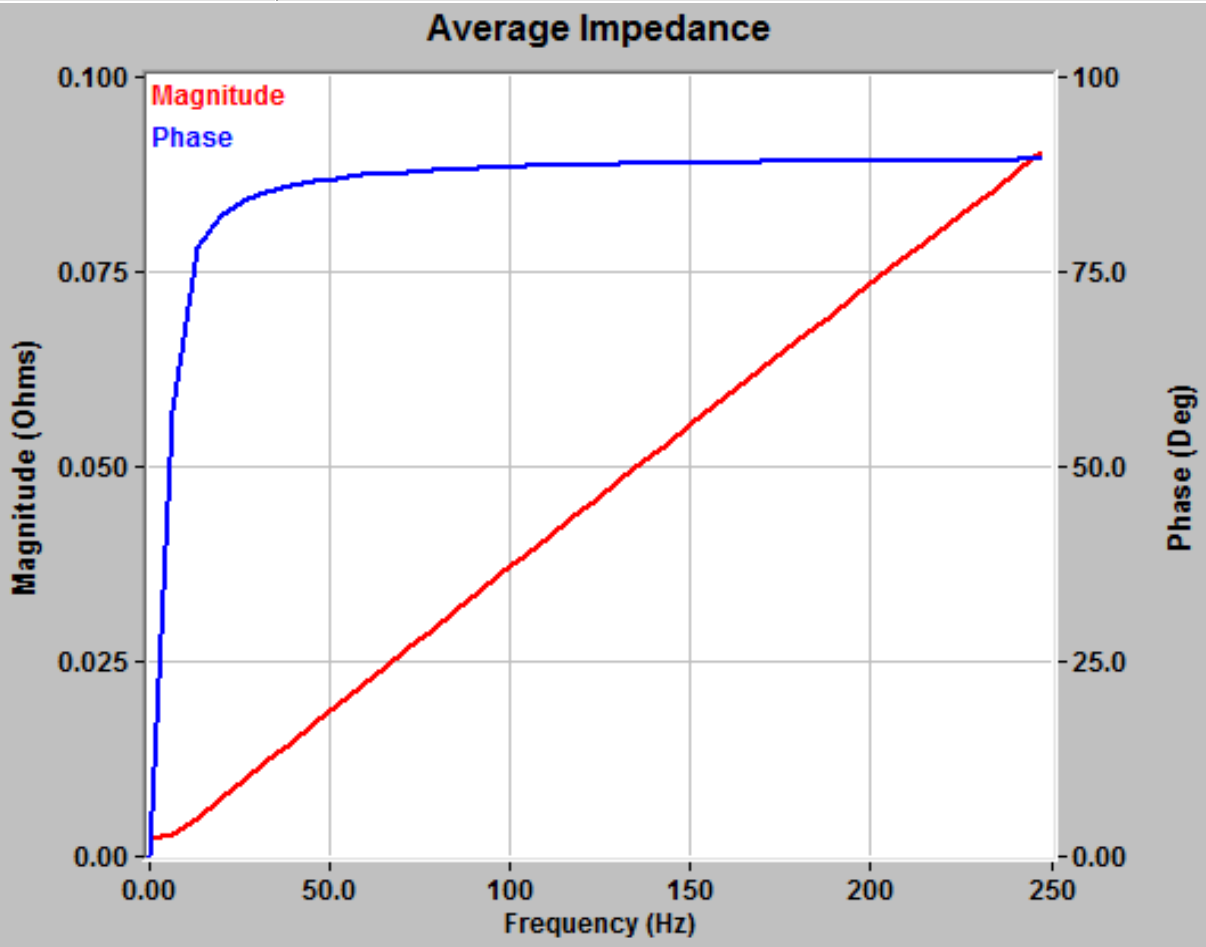
Resistance 0.001002 Ohms

Reactance 0.02215 Ohms

Inductance 0.05874 mH

SGM **Impedance Report** Close

Case Name	Case 1 _PTP	Time	11/12/2013 08:45
Description	From Common point 4 to 14		



Cursor Values

Frequency 60.00 Hz

Impedance 0.02236 Ohms

Phase 87.43 Degrees

Resistance 0.001002 Ohms

Reactance 0.02234 Ohms

Inductance 0.05925 mH

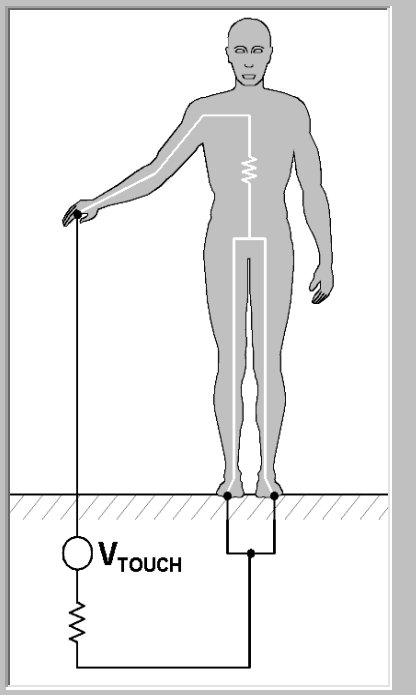
Hood Patterson & Dewar

4. Touch Voltage Measurement

Case Name	RTA_SUBSTATION_1_2	
Fault Current	1000.0	Amperes

Touch Voltages

At Probe 1Y	2.75	Volts
At Probe 2Y	3.49	Volts
At Probe 3Y	1.77	Volts
At Probe 1B	3.51	Volts
At Probe 2B	5.25	Volts
At Probe 3B	5.92	Volts

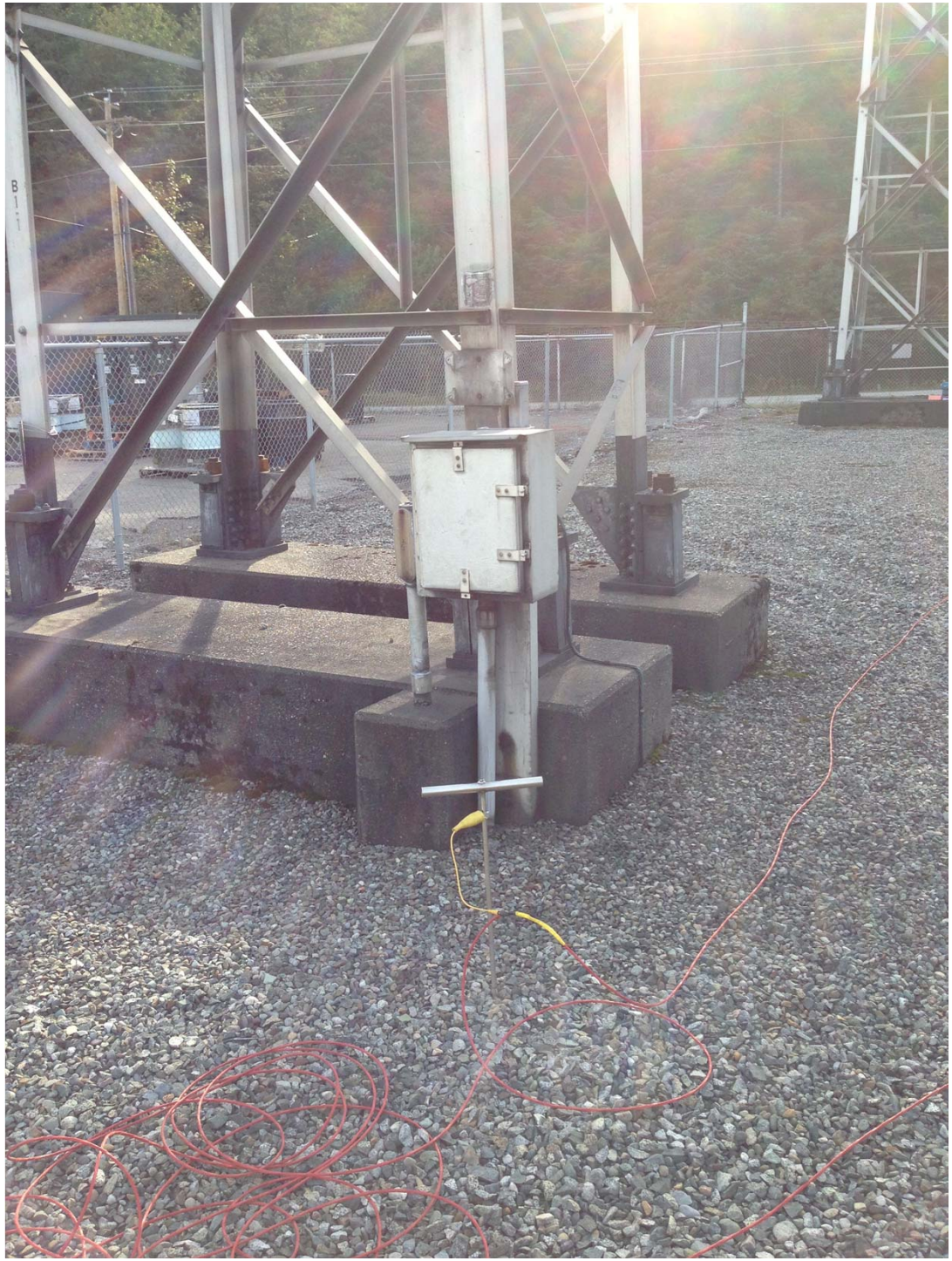


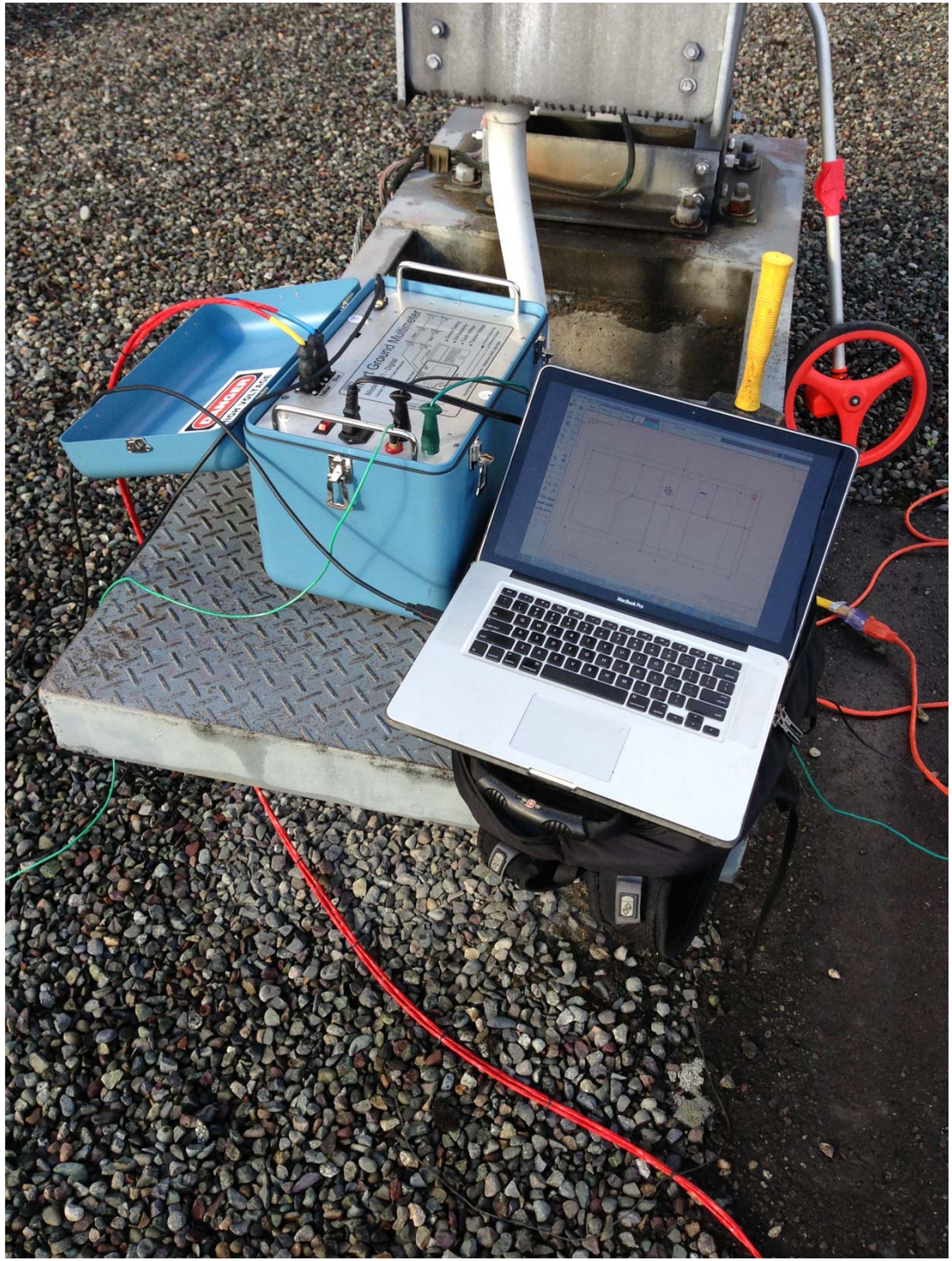

DANGER
HIGH VOLTAGE
TESTING
IN PROGRESS
Multimeter


440
1
2
3


HOLD
OFF 4240


MK40




Ground Multimeter
MacBook Pro

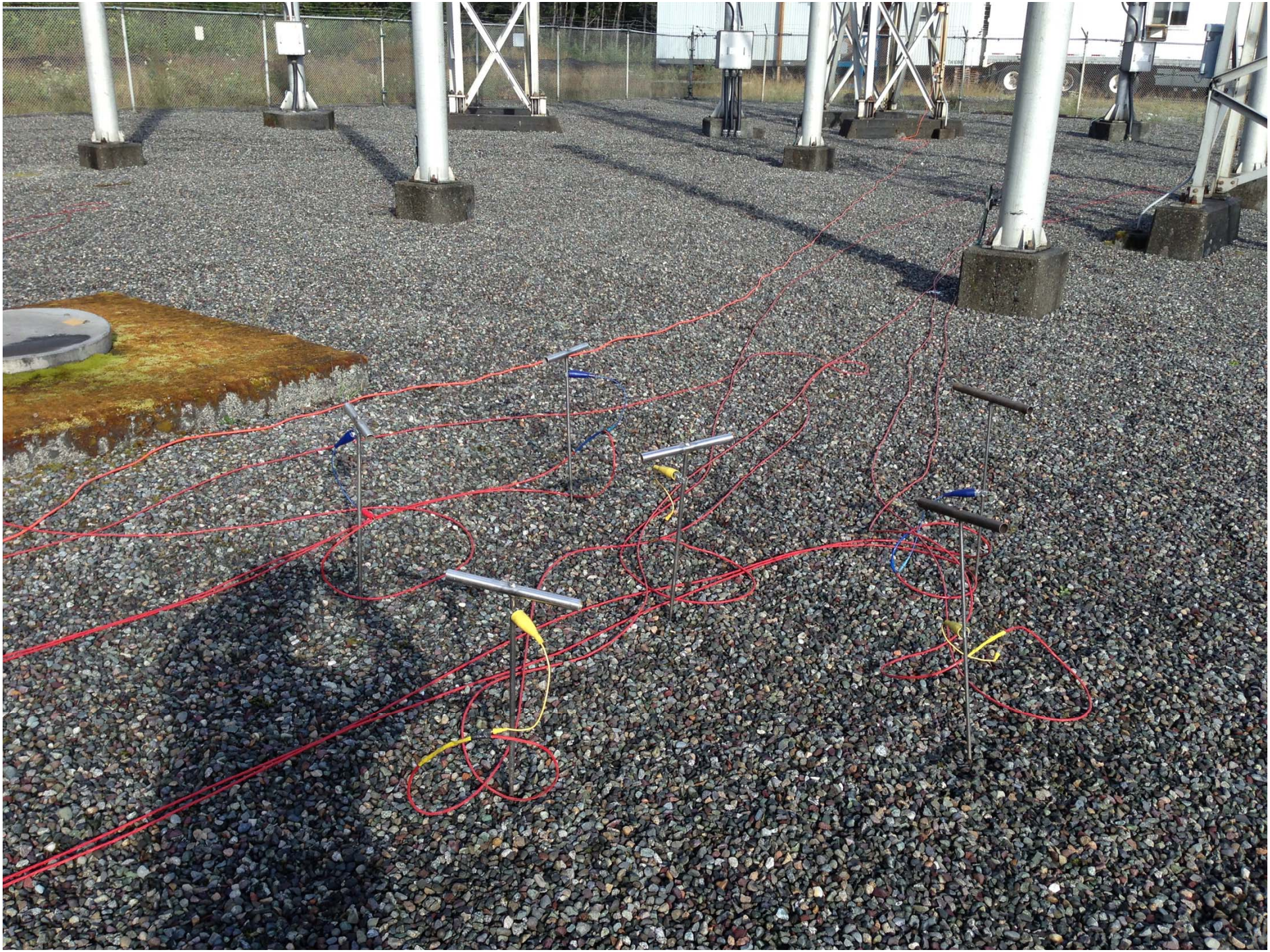
5. Step Voltage Measurement

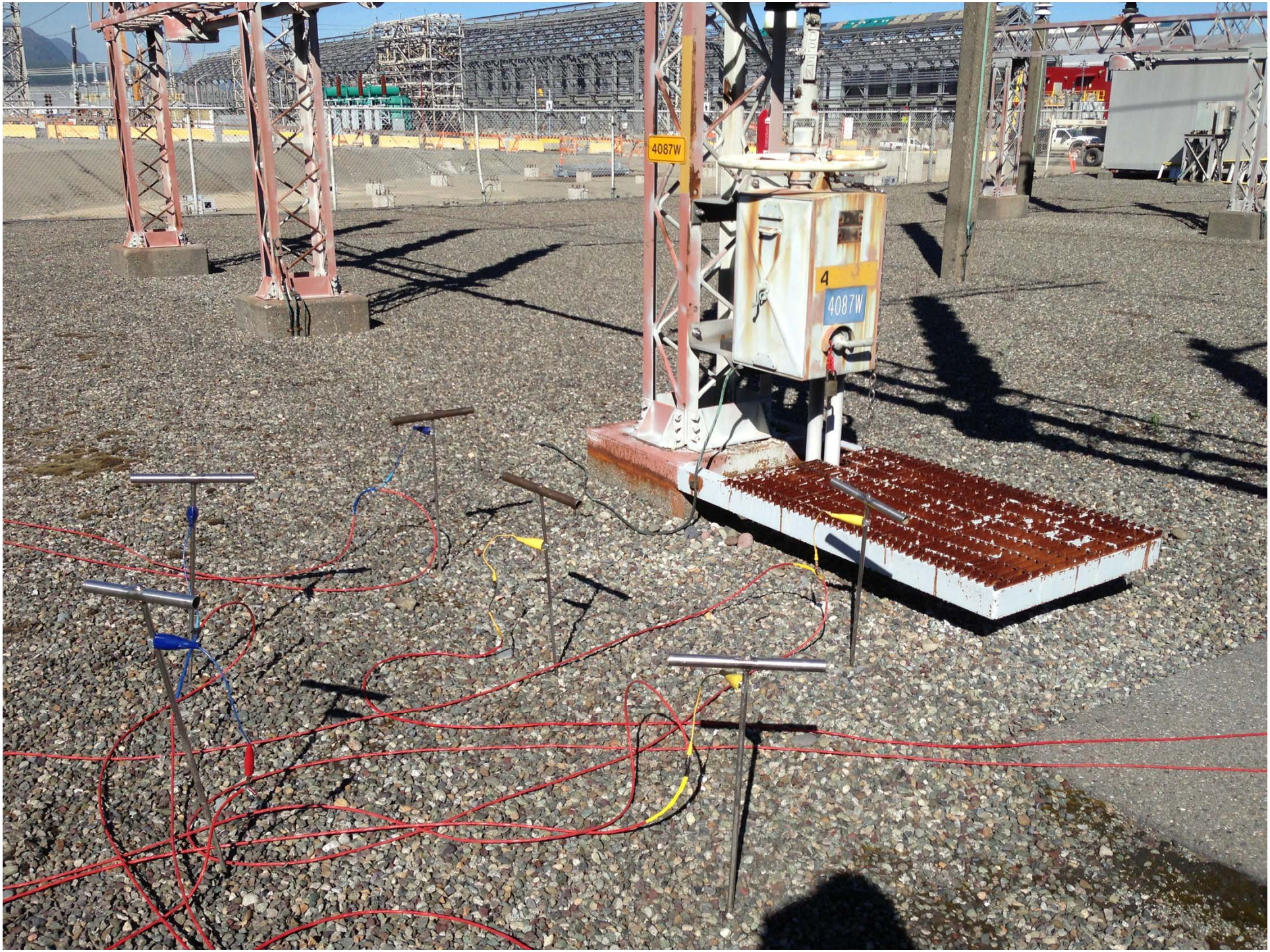
SGM Step Voltage Report

Case Name	SUBSTATION_1_2

Fault Current	1000.0	Amperes
Step Voltage	0.34	Volts

Return




4087W
4
4087W

Locating the Current Return Probe