Tower Measurement With Model 6472 and 6474

Appropriate for testing:
Monopole
H-Frame
Tri-leg
and Lattice towers

Connect green Current (**E**) and black Voltage (**ES**) test leads to the grounding system to be tested using separate cables. Connection points should be side by side and above the GroundFlex®
(Rogowski) coil when testing tower leg resistance/Impedance. See Figure 1

Wrap the GroundFlex® coils around the Tower leg(s). The more turns you use, the more robust the measurement will be - all coils must have the same number of turns around each tower leg.

All coils must be installed in the same rotational direction either clockwise or counterclockwise (note arrow orientation on each GroundFlex® sensor) - the coax cables on the GroundFlex® sensors must come out in the same direction. On towers with 3 or 4 legs, the sensors must be in sequence from one leg to the next.
(SEE Figure 2)

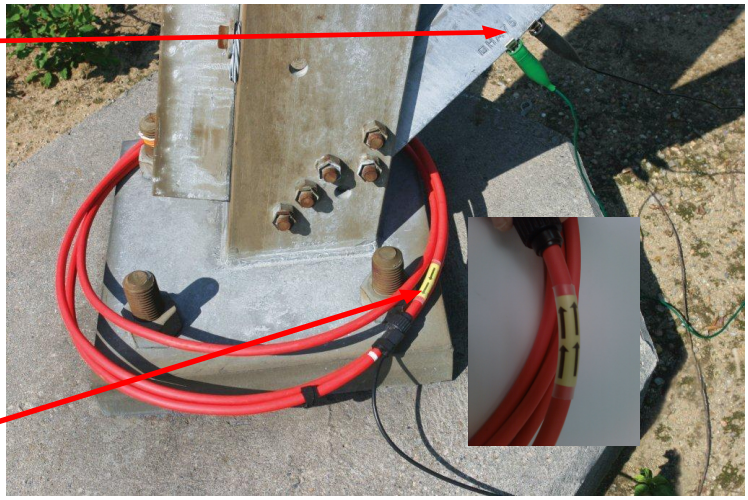


Figure 1

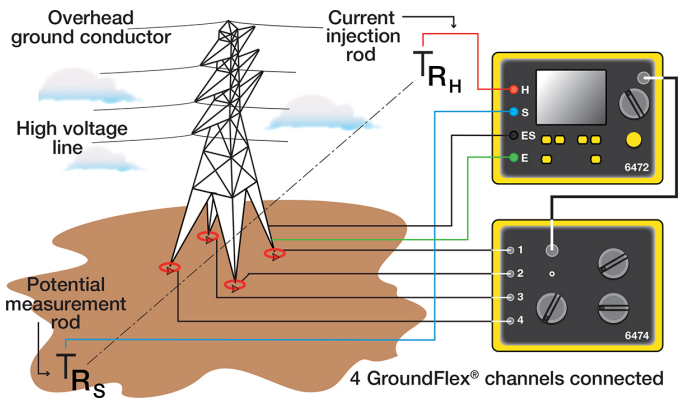


Figure 2

Choosing the positions for the **H**, **S** electrodes:

If possible, position the H and S electrodes 90° to the High Voltage (HV) line, one to the left and the other to the right with respect to the HV transmission line. If this is not possible stay at least 30° off parallel to the HV line. The minimum distance should be 150 – 300 ft. (50-100m). **Under no circumstances** place an electrode in the area and parallel to the HV-line. Connect the H electrode using the red (H) lead and the S electrode using the blue (S) lead. See Figure 2

NOTE: The resistance for the H and S electrodes to earth should each be below 1kΩ to ensure good test results

Figure 3

For the most accurate Measurement roll the cable completely out to eliminate any inductance problems in locations with high overhead energy from the HV line. Normally errors are in the milliohm region when the cables are not fully removed from the spool. (See Figure 3)

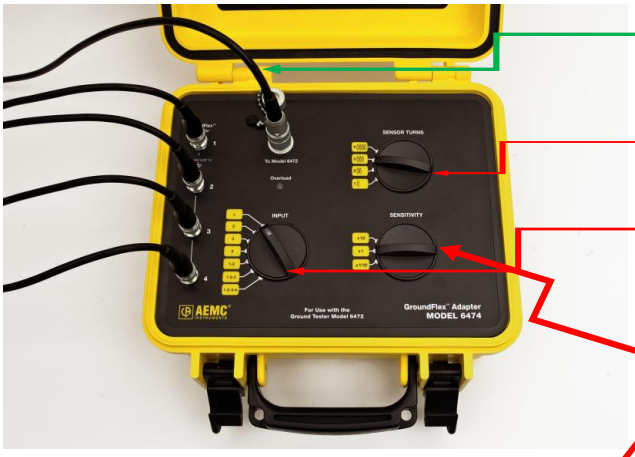


Figure 4 (model 6474)

Confirm that the umbilical cable connection between the 6472 and 6474 is secure. Check the position of the rotary switches (Input, Sensor Turns and Sensitivity) on the 6474 to be sure they match the test requirements. (See Figure 4)

The number of turns must correspond to the number of turns used on the installed GroundFlex® coils on each tower leg.

Use input switch position1-2-3-4 for measurement of the total pylon earth current on four leg towers. Use the corresponding switch position for 2 (1-2) and 3 (1-2-3) leg towers.

Start the test with x10 amplification.

Figure 5 (model 6472)

Turn the rotary switch on the model 6472 to the GroundFlex® position. The 6474 amplifier will turn on after the 6472 is powered on and the calibration of the connected GroundFlex® sensors will be varified. The Overload LED will come on for a few seconds during power up. If this LED is flashing continuously and the 6472 beeps continually,when the current in the GroundFlex® sensor(s) are too high for the selected amplification. Reduce to X1 and then to X1/10 if necessary, If it is still present in the 1/10 position, then reduce the number of turns of the GroundFlex® sensors.

First check: (See Figures 5,6,7 and 8)
Disturbance voltage measurements on the S Probe and the H Auxiliary electrode will run continuously as long as a test has not been initiated with the START button.

Press the DISPLAY button until U-Act. and U_{S-ES} or U_{H-E} is shown. (U-Act. refers to live actual voltage)

U_{S-ES} = measured voltage between S and ES

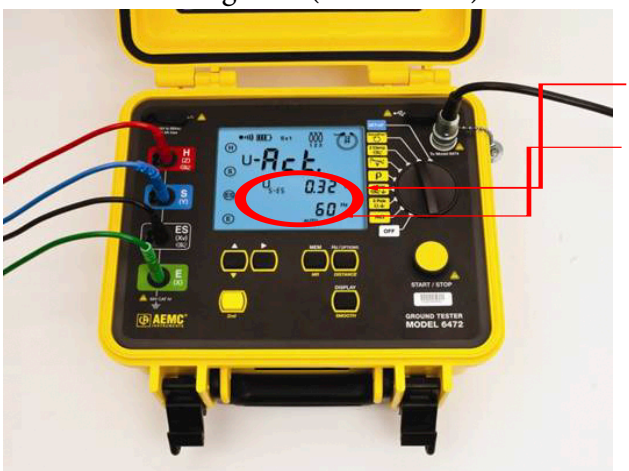


Figure 6 (model 6472)

Press the DISPLAY key again until U-Act. and U_{H-E} is shown.

U_{H-E} = measured voltage between H and E

The frequency of U_{S-ES} or U_{H-E} is shown when the corresponding voltage is higher than 0.1V.

The measured voltage is caused by the current flowing through the tower into the Earth.
When $U_{H-E} = U_{S-ES}$, then the electrodes are placed far enough from the potential shells of influence of the tower legs. If one of these values is smaller, you should reposition the electrode which shows the smaller voltage, further away from the HV-line and check U_{S-ES} and U_{H-E} again.

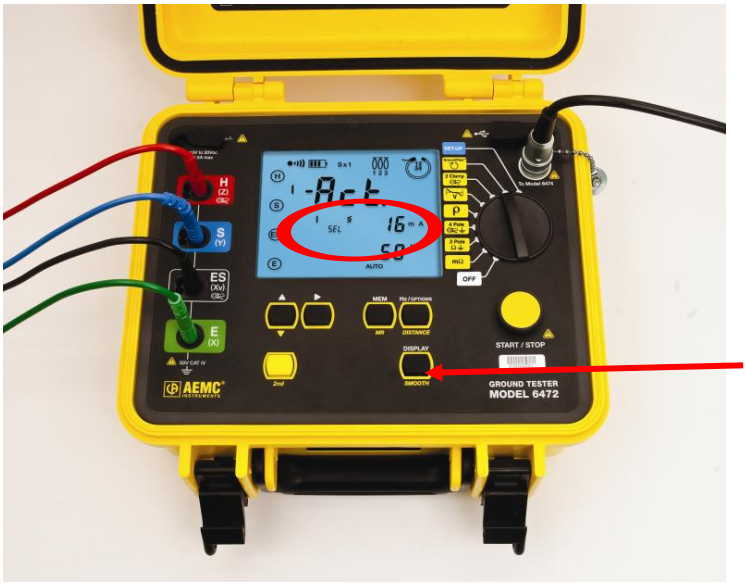


Figure 7 (model 6472)

When this condition is achieved, the results of the active measurement (pressing the START-button) will be reliable.

When both U_{S-ES} and U_{H-E} are nearly zero, then the HV-line is not in service or the overhead ground conductor is completely corroded or not connected.

In this case, the total pylon current will be also nearly zero.

Press the DISPLAY button until I_{SEL} appears. This is the total pylon earth current, measured by the 4 GroundFlex® sensors (channels 1-2-3-4 selected for a 4 leg tower)

Figure 8 (model 6472)

Next press the DISPLAY button until R_{PASS} appears.

A leakage current I-SEL, induced in the pylon, produces a voltage drop U_{S-ES} (potential difference to Earth) on the earth-resistance of the pylon.

Knowing I-SEL and U_{S-ES} , the 6472 can calculate R_{PASS} (passive earth resistance)
It has the advantage of being measured at the nominal frequency of the network, but is also influenced by the load fluctuations in the network as well and by the potential sphere of influence of the HV-line.
When the tower earth resistance is actively measured and is nearly equal to R_{PASS} , then the result will be reliable, otherwise, the potential relationship during the active and passive measurement will be different.

Second check: (See Figures 9 and 10)

Currents in the tower legs are measured continuously as long as the START-button has not been pressed. Switch the model 6474 to INPUT 1, select I_{SEL} on 6472 with DISPLAY button.

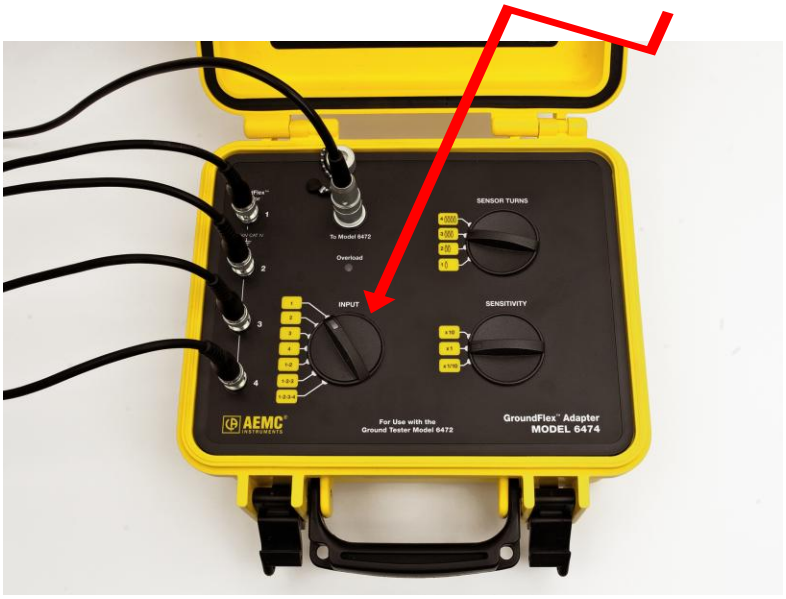


Figure 9

Figure 10

Check the current in each tower leg by switching to channel 1then 2 then 3 and 4 noting the measurements of each- in this way you can find corroded and/or unconnected earth connections as indicated by the fact that there is no current flow.

Finally, check the sum of all leg currents channel 1-2-3-4 - if it is approximately equal to the sum of the all individual leg currents, then the static wire (overhead ground conductor) is bonded to the tower properly. If not, this connection is probably corroded and only a small current will be flowing in the tower legs, which will be induced in the tower grounding. The sum will be very low, despite that single currents can be higher because they can flow in different directions.

The measurement of R_{PASS} for individual legs has no value - even in the case when individual legs are not connected together. Below ground level, they will still influence each other.

Third check: (See Figure 11)

Start a measurement with a long press on the 6472 START button in the 4-pole switch position.This will initiate the test using 32 Volts and will provide the full compliment of test results including auxilary rod (H and S) resistance.

The measurement will be conducted at 128Hz. When a measurement is initiated with a long press on the STARTbutton (by holding down for approximately 2 sec until a second beep is heard), you will then get additional results including the resistances of electrodes R_H, R_S - both should be below 1KΩ if you want to perform a good quality SWEEP test up to 5kHz.

If Rh or Rs is higher than 1kΩ, you can place more electrodes in parallel with each of them or you can moisten the soil in the area where the electrodes are placed. Parallel electrodes shall be placed at a distance of approximately 4x the depth of the H and S electrodes. R_H should be as low as possible, because it determines the test current.

The higher the test current, the better the measurement precision - take into account, that much of this current will flow through the overhead ground conductor and only a small percentage will flow through tower legs into the earth! Test currents below 3mA can cause unreliable results as indicated by the flashing grearer than and less than symbols to the left of the reading.
When any input symbol is blinking on the display, it means, that the corresponding lead is disconnected or broken. The measurement can be performed only if all connections are good.

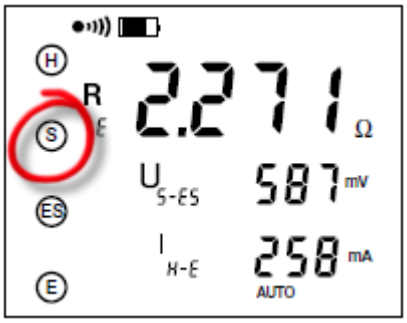


Figure 11

Measurements:

When all parameters are in the "green zone" (proper range), 3 typical measurements on the tower can be accomplished.

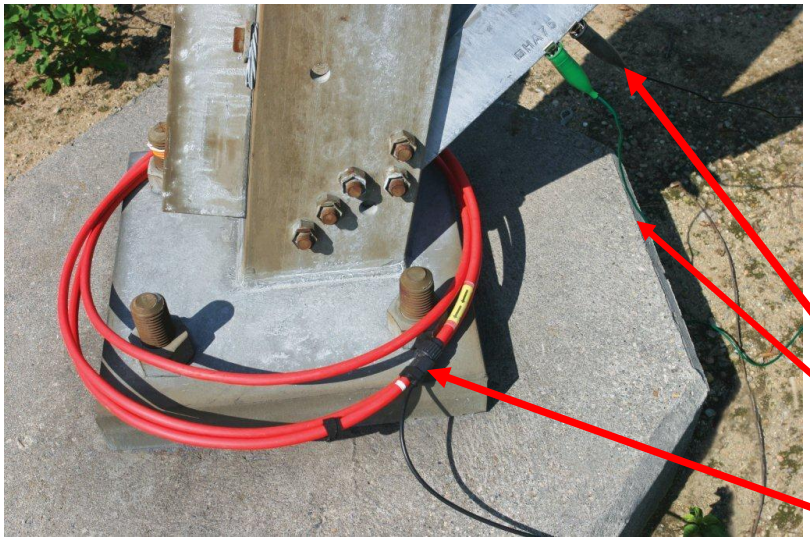


Figure 12

1st measurement: (See Figure 12)
(long press of the START button)

SWEEP Mode
GroundFlex® sensors measurement into the Earth
Current injection and voltage measurement points (green and black leads) are above the GroundFlex® sensor.
Potential measurement **E_S**
Current injection **E**

Current measurement with GroundFlex® sensors

Figure 13

2nd measurement: (See Figure 13)

SWEEP Mode
GroundFlex® sensor measurement into static wire (overhead ground conductor)
Move the current injection wire **E** so it feeds through the GroundFlex® sensors on the tower leg and connects next to the potential connection

ES potential connection remains unchanged

Current injection wire **E** passes up through the GroundFlex® sensor on the tower leg and connects next to the E_S connection point.

NOTE: In SWEEP mode a long press is automaticaly initiated and the measurements at each frequency used in the sweep are stored in memory

Third measurement: (See Figure 14)

SWEEp Mode

4-pole Earth-impedance measurement (sometimes called "lattice network" measurement).

In this case the total earth impedance of all components of the grounding system as if it is one resistance/impedance will be measured.
The overhead ground conductor (OGC) connects the grounding systems of all towers in parallel at low frequencies, but at higher frequencies the inductance of the OGC starts to separate them such that the effective impedence of an individual tower can effectively be measured.

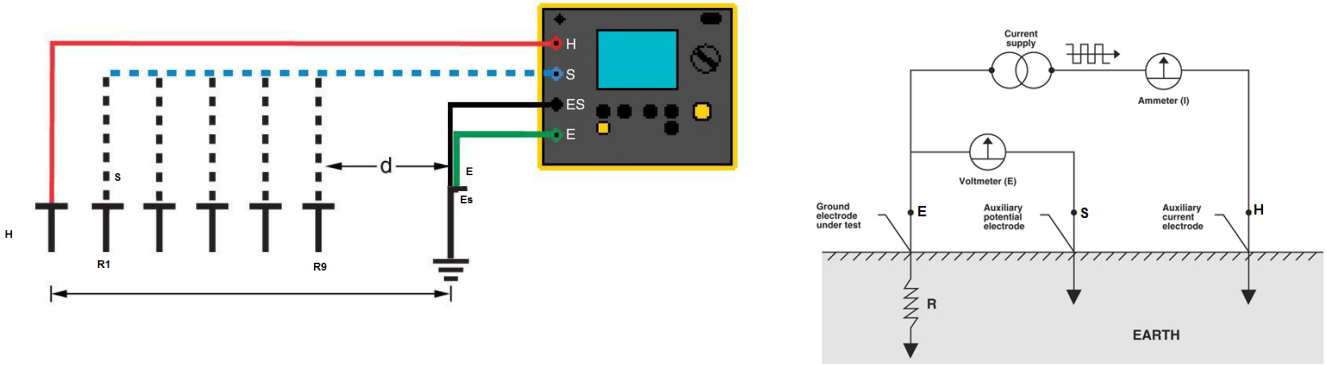
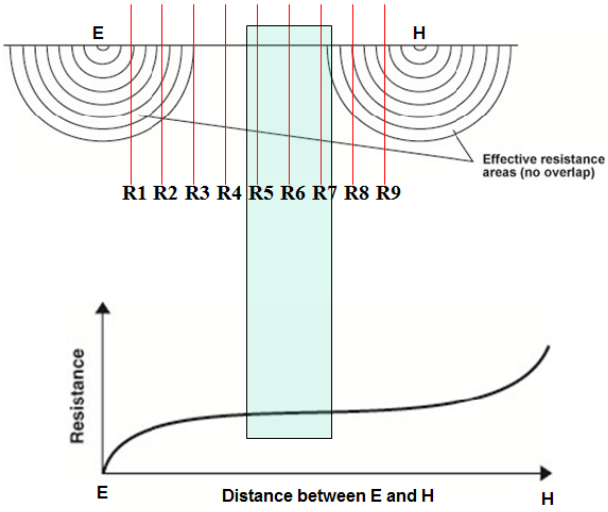


Figure 14

Measure the resistance/impedance in 10% steps between E and H.
Look for the plateau readings (usually between 50% and 70% distances to find the effective resistance/impedance of the structure under test.



Test sequence recap:

First check

- Measure disturbance voltages U_{ACT}, U_{S-ES}, U_{H-E}
- When U_{S-ES} and U_{H-E} are close in value to each other then the H and S electrodes are out far enough. If they are different move the electrode with the lower voltage out further and recheck.
- When U_{S-ES} and U_{H-E} are close to or equal to zero, the OGC is badly corroded ornot connected
- Next check R_{PASS} and note it for later use

Second check

- Check the current in each tower leg I_{ACT}/I_{SEL} to find corroded or unconnected grounding points.
- Next if the sum of all legs is approximately the same as the sum of all individual legs then the OGC is in tact.

Third check

- Press the START button with a long press to begin active measurements. Note the resistance of
- R_H and R_S. If either or both are above 1kΩ, add more electrodes or moisten the soil around them to lower their resistance to earth.
- 1st Measurement use SWEEP mode with black and green wires connected to the tower leg
- above the GroundFlex® sensor
- 2nd Measurement use the SWEEP mode with black wire connected to the tower leg above the
- GroundFlex® sensor and the green wire connected to the tower leg passing up through the GroundFlex® sensor and connected next to the black lead.
- 3rd Measurement use the SWEEP mode to perform a 4-pole impedence measurement

Glossary Of Terms

E Terminal – Also known as the X terminal is a **green** colored terminal and is the current injector terminal
ES Terminal – Also known as the Xv terminal is a **black** colored terminal and is the voltage measurement terminal
S Terminal – Also know as the Y terminal is a **blue** colored terminal is the voltage return terminal
H Terminal – Also known as the Z terminal is a **red** colored terminal and is the current return terminal **HV Line** – is the power line running from tower to tower
Top Line – is the overhead ground conductor also known as the sky wire in some areas.
U_{ACT} –is the real time voltage measured before running a test
I_{SEL} – is the total real time leakage current measured
R_{PASS} – is the passive earth resistance measured at normal network frequency.
SWEEP Mode – is a measurement mode where the 6472 takes measurements at 14 user selected frequencies between 40 and 5078 Hz.
4 Pole – refers to the number of terminals on the 6472 used in performing a test.
Green Zone – refers to all conditions being within range to properly take measurements
GroundFlex® Sensor - Also known as AmpFlex Sensor or Rogowski coil which is a flexible device used to measure AC current flow.

U - International symbol for Volts
U_{S-ES} - Voltage measured at the potential terminals
U_{H-E} - Voltage measured at the injection terminals
R_H - Resistance of the injector electrode
R_S - Resistance of the potential electrode
OGC - Term used to indicate the overhead ground conductor also called static wire or sky wire

Green Zone Conditions:

R_H and R_S - Resistance of each should be less than 1 kΩ if either or both are above that add more auxliary electrodes in parrallel or moisten the area around the electrode.
I-ACT should be a minimum of 3 milliAmps
U_{S-ES} and U_{H-E} The voltage measurenet for these two should be close to each other. If they are not within a few volts of each other, move the auxliary rod with the lower value out further and retest.