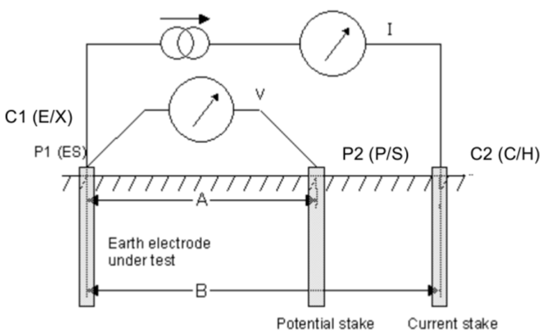
Limitations of '3-Pt' Earth Resistance Testing

The three-point method is widely used for assessing the performance of an earthing system, but many asset owners and testers alike may not be fully aware of the limitations of this test method. Without such an understanding, results can have limited benefit and in some cases can be misleading.

Owners of high voltage assets are required by standards, codes and regulations to take reasonable steps to control foreseeable hazards to people and equipment. Many earth fault scenarios fall into this category and as such, supervision of HV earthing systems is required.

One test commonly used to measure the resistance of an earth grid is the 3-point test. It is relatively straightforward and can usually be performed in around an hour. A three or four terminal meter is connected to the earth grid under test, and two electrodes are installed at particular distances from the grid. The meter then passes current through the grid and back via the 'current' electrode and by measuring the voltage at the intermediate electrode it calculates a resistance to display to the tester.



Three-Point Method

Compared to more complex methods, it requires relatively little lead deployment and can give an answer with a single voltage measurement. When performed correctly on suitable assets, it can determine the grid resistance to better than ±50% and for some situations this is perfectly acceptable. It therefore remains a useful part of an earthing system supervision and maintenance strategy, or commissioning validation of less complex assets.

Given the apparent simplicity of performing the test, it can often be assumed to be a test that's easy to get right, but that's not the case. There are a number of mistakes which are commonly made when performing this test, and even if these are avoided, there are lots of situations where this test is completely inappropriate.

The simplicity of the method comes at a cost to the accuracy, so it is important to know how accurate you need the test to be, and whether the 3-point test is the right one for a given situation. It is a test which is usually only satisfactorily performed on relatively small (<10m) and higher resistance earth grids (>5Ω) with no other bonded auxiliary paths.

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Various Earth Resistance Testing Instruments

Assumes No Interference

The use of a single point for the 'voltage' measurement of the asset's earthing system (rather than a full fall of potential in a current injection test) relies upon an expectation that there are no buried conductive elements in the surrounding soil. Even after taking a number of measurements around the 62% point to confirm no dramatic local interference exists, buried elements can cause significant errors, both high and low. Examples include a single distribution neutral running to a small number of houses from a poletop transformer's HV stake. This can create errors of up to 5 times in either direction depending on the layout of the buried items.

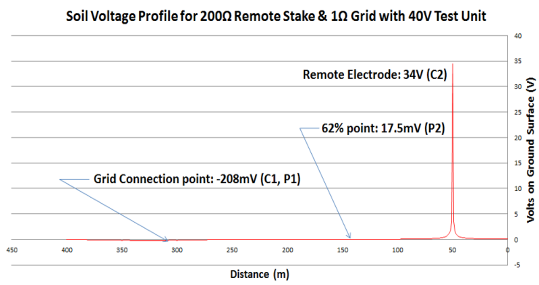
Reliance on Certain Soil Conditions

In the case of a low-on-high resistivity soil structure the test can conclude that the resistance is much lower than is really the case. Where buried elements are present this soil structure greatly worsens the effect of the interference.

Intended to Test Simple, Higher Resistance Grids

Where an earth grid is small (e.g. on a pole-mount transformer, ABS, etc), reasonably separate and electrically isolated from other conductive elements, the three-point test can give quite accurate results in uniform (or homogeneous) soil models. Typically it can be used successfully for isolated distribution substations and other similar assets, where there is only up to 5 HV earth stakes (usually over 5Ω).

The test currents used by three-point testers are often less than 300mA at <50V, and this limitation reduces the accuracy as the physical size of the grid increases.



The Three-point Method on a Low Resistance Grid

As the tested resistance reduces, the 3-point test gives a further reduction in the value shown for the item under test. For example, if the tested item is 1Ω and the remote electrode is 200Ω (the best case for a single 30cm deep remote stake), interference from the remote electrode of just one tenth of one percent (0.001) will show up as a 20% change in the resistance of the item under test. For systems with auxiliary paths (eg utility zone substations or mine main incomer substations) this error can easily become a factor of three.

It's also important to understand that for this measurement, the meter will be measuring

An example of a poorly executed three-point test

<250mV of test signal. In the presence of live power systems and electrically noisy environments, it's clear to see that the test readings will suffer from measurement accuracy problems in addition to the above concerns.

Most of the test units used for the three point test do not allow measurement of the test current being conducted by auxiliary paths which often exist in anything but the most simple of systems (eg any substation with connected earthwires or cable screens). These current distribution measurements are critical to understanding the performance of such earthing systems and in most cases require a full current injection test, at least to establish a baseline.

In the worst case, the three point test is performed on an asset which is interconnected to all others in the vicinity, and these completely encompass the test deployment. In such a case the result is not at all representative of the performance during a real fault. In the case shown above, the 3-point test measured 0.17Ω, whereas a current injection test showed 0.02Ω – *out by over 8 times.*

The Earth Fault Details are Critical

Knowledge of the fault current and clearing time at the selected location is critical to the accurate assessment of the safety of the system. Additionally the fault rate or likelihood, and an understanding of the contact scenarios and personnel proximity may be useful.

Without understanding the original design criteria, and perhaps confirming that these remain valid, the measurement is simply one of resistance, whereas the hazards to personnel are principally voltage-based. The three-point resistance test does not assess any of these hazards to personnel.

If the fault data has changed since the original design or previous assessment, further analysis is required to confirm if the earthing system remains appropriate.

SUMMARY

The three point test can be a useful tool for assessing the earthing elements of certain HV assets. Generally these are simpler systems with resistance over 5Ω, where the original design's compliance criteria and soil model are well understood, and even though the test isn't completely 'repeatable' it will be good enough.

In numerous instances alternative but similarly straightforward methods exist for assessing the performance of an earthing system. These include visual inspection, DC continuity testing or loop impedance measurements. In some cases however the proper assessment requires an earthing current injection test.

Key Problems to Watch Out For

- Too close to other conductive assets.
- Earthing system too complex for this test resulting in errant reading – possibly high or low.
- Non-uniform soil conditions cause reading error.
- Fault data has changed and the target resistance is now no longer appropriate (eg system changes means increased fault level).
- Earthing system impedance too low causing even lower resistance reading (measurement error).

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