Ground Coupling

Grounding and ground testing are stand-alone functions in the worlds of electrical theory and application. Most applications deal with man-made objects, making them perhaps a bit easier to conceptualize and manage. But grounding is, in theory, an electrical connection to the entire planet, and in practice to a poorly defined and potentially irregular portion thereof. That is to say, most of the planet doesn’t contribute a measurable increment to the on-site grounding resistance. It is of some interest to the realization of theoretical development, but not to assessing the performance capabilities of the buried electrode. Fortunately, that is confined to a much more workable area around the general vicinity. Accordingly, problems and uncertainties are reduced dramatically, but not eliminated.

The working area around the site still has multiple unknown factors with which to deal. Soil composition can vary widely, especially at graded sites. Underground objects like boulders, water table, power cables, and water pipes all influence grounding performance, and their existence may not even be known. Superimposed on this are daily and seasonal variations in factors like temperature and moisture content. Because of these variables and inconsistencies, it is much more difficult to install and test grounding by merely following step-by-step recipes than it is with rigorously designed and conforming man-made circuitry. This is by way of preface to the problem of ground coupling. The problem will be defined and explained first, and then its effects discussed.

Research on ground coupling has been pioneered by the national utility of France, Electricité de France (EdF). Their research discovered that when isolated grounding electrodes are installed in too close proximity, they can develop a resistance between them that is superimposed upon their resistance to remote earth. This phenomenon has two profound effects, one on safe operation and the other on testing and measurement. Accordingly, EdF has developed a recommended procedure for testing and evaluation.

When a second isolated electrode is to be installed in proximity to another, the separation distance is evaluated through the performance and correlation of three measurements obtained by the application of two well-known standard test procedures. One of these is commonly known as the 62% Rule and the other is often referred to as the Dead Earth Method. As a common example described by EdF, a pole-mounted transformer may have an upstream lightning-protection ground to the case, and somewhere downstream an equipment or panel ground, depending on the prevailing electrical scheme. These are isolated across the primary and secondary of the pole-mounted transformer.

**Coupling Coefficient — The Measurements**

![Figure 1](image-url)
In order to determine whether a coupling resistance exists, two imaginary lines are drawn first. One is between the two electrodes in question and the other at right angle to the first and equidistant between the electrodes. The ground tester is positioned at 20 meters along this second line, and the connection of the downstream electrode to the system is lifted. This electrode is first tested for resistance to remote earth by connecting one pair of terminals (or the common of a three-terminal tester) to it, and then extending the current probe 100 meters farther along the same line. The potential probe is located 50 meters from the tester along the same line (i.e., 70 meters from the line between the two electrodes) and a measurement taken. Using EdF’s notation, this can be designated \( R_{\text{neutral}} \) (Fig. 1). The second test is performed on the upstream electrode in the same manner. All that is changed is the connection to the electrode; the current and potential probes remain in their original positions. This measurement can be designated \( R_{\text{grounds}} \) (Fig. 2).

![Figure 2](image)

At this point, two bits of data have been collected, the resistances to remote earth of the two isolated electrodes. These two tests employ the 62% procedure for determining the measurement. For the third and final test, the probes are disconnected and the current and potential terminals connected to the first electrode. Each of the pairs of terminals is now connected to one or the other of the electrodes under test. The tester is energized and a series resistance measurement taken (Fig. 3). This is a two-point test (for the two points of contact with ground), but is also known widely as the dead earth test, not for the resultant condition of the operator but because it was devised as a short cut method that measured resistance to an arbitrary remote return presumably of negligible contribution, frequently the water pipe system. Not being part of the electrical system, this return was referred to as a dead earth. This measurement can be designated \( R_{\text{grounds/neutral}} \).

![Figure 3](image)

Having made the requisite measurements and gathered the data, all that remains are two simple calculations, devised by EdF. The first is the calculation of the actual coupling resistance:

\[
R_{\text{coupling}} = \frac{R_{\text{grounds}} + R_{\text{neutral}} - R_{\text{grounds/neutral}}}{2}
\]

This is the value in ohms of the resistance that exists between the two electrodes, in addition to their individual resistances to remote earth. Next, a figure of merit called the coupling factor is calculated by the formula:

\[
k = \frac{R_{\text{coupling}}}{R_{\text{grounds}}}
\]

To be free of coupling influence, EdF mandates that \( k \) be less than 0.15:

\[k < 0.15\]

If this condition isn’t met, the more serious concern is that with safety. If an event…say, a lightning stroke…occurs on the upstream side, this is expected to be safely dissipated by the associated electrode. But the coupling resistance can cause a voltage gradient and current flow between the two electrodes, and hence a voltage rise on equipment on the downstream side. What was intended as two separately protected systems now have coupled to produce a dangerous situation between them.

Furthermore, such an unanticipated and undetected additional resistance can produce errors in measurement which can, in turn, lead to a further safety hazard by creating a false sense of protection. An additional resistance may exist that the operator is unaware of and unprepared to deal with. A common example of how a problem might arise is in the testing of on-site grounds where the system has been connected to the utility. Common wiring practice will have the utility’s ground connected in parallel with the facility ground. A perfectly reliable test can be performed, but the limitation is that the result will be for the whole system, not just the resistance of the facility ground. An enhanced-feature ground tester may be designed to deal with this situation by including an on-board current clamp calibrated to measure only the frequency put out by the particular tester.
When clamped downstream of the test connection, the current clamp is intended to send to the measuring circuit only the test current accommodated by the facility ground while ignoring that portion flowing to the utility.

A typical problem arises when the electrode under test has been augmented by, say, a connection to the water pipe system. The operator may not even be aware that such a connection exists, and it well may pass very close to the test electrode, thereby establishing a coupling resistance. Now, when the tester is energized, a counter emf can be established by the current flow through the water pipe system, thereby affecting the amount of current seen by the tester and distorting the measurement. With no awareness of the possibility of coupling, the operator bases a judgment on misleading data, which could be costly. With proper awareness, a more thorough investigation of the site will avoid costly errors.

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