In previous columns, we have examined the familiar and popular methods for testing the resistance of electrical grounding electrodes. To the uninstructed, these methods may at first appear overly detailed, tedious, and time-consuming. They typically involve careful measuring and positioning of test probes, repeated test measurements, and often graphing and/or mathematical proofs. Compared to operating a multimeter, this can look like too much work!

But test methods exist and are precisely described, because it is not the resistance of the electrode itself that is being measured, but its electrical relationship to the surrounding earth. The test item isn’t so much the electrode as it is the entire planet Earth or, ...for practical applications..., that portion immediately surrounding the buried electrode. This is a radical divergence from testing a piece of equipment, where circuitry is well-defined and current flow reasonably predictable. In routine electrical testing, the test meter is connected so as to become an extension of the circuitry, and the test is fairly comprehensible. A voltmeter, for instance, bridges the load and measures the electro-motive force across it. In most electrical equipment, the better the current can be controlled and directed, the more efficient the device becomes. But grounding is the opposite. Since the electrode’s function is to divert current (from the facility), the less restricted it becomes, the better. The earth fulfills this requirement adequately by its enormous volume, but that also makes measuring it a challenge. Hence, the need for specific and well-defined procedures.

Test methods exist because there are so many challenges to be addressed such as poor soil, huge electrodes with large electrical fields, and limited and highly obstructed workspaces. Over many years of fieldwork, different methods have been devised to meet these varying challenges. Methods serve the purpose of proving the result and/or saving time and reducing workload. Some are also adapted to dealing with specific problems, particularly limited space. Some methods, like fall-of-potential, provide excellent proof of reliability but at the expense of time and work. Others, like the 62 percent method, save time, but the result must be accepted without proof. Still others, like simplified fall-of-potential, compromise by reducing test time, yet still provide a (mathematical) proof of reliability. Methods designed to work in limited space, because of the inherent danger of getting a false reading with restricted lengths of test leads, must by their nature include some means of proof, whether mathematical (slope method) or graphical (intersecting curves).

All of these methods have been described in detail in earlier columns. In this issue, we will examine the four potential method. This is another method specifically intended to meet the problem of testing large ground grids that would otherwise require impractically long test leads and, therefore, is frequently employed for substations and power stations. Such grids tend to cover large areas and also have complex structures of different sized rods. When approached by conventional methods, not only may there be insufficient space to accommodate the required length of test leads, but the electrical center of the system is indeterminate. Trying to use a method like the 62
percent rule, which is based on fairly precise measurement for positioning of the test probes, would introduce too large a potential error. The leads would have to be measured from an arbitrary point, which could be a considerable distance from the electrical center. With four potential, the tester is attached as usual to any convenient point on the edge of the grounding system. The current probe is stretched out to whatever maximum convenient working distance can be obtained, but it is still advisable to do all that is possible in order to gain a substantial span.

![Image](image.png)

**Figure 1 — Four Potential Method Test Configuration.**

Critical readings are then taken with the potential probe at 0.2, 0.4, 0.5, 0.6, 0.7 and 0.8 the distance to the current probe (Fig. 1). If the local situation followed the ideal model, these points could simply be plotted into a fall-of-potential graph, and the job would be done. But four potential works where fall–of-potential would produce an ambiguous and unreadable graph. A mathematical proof accomplishes what a graphic cannot. It determines at what point the resistance of the test electrode maximizes while masked by the superimposed resistance associated with the current probe. This could also be visualized as the theoretical 62 percent point if the test ground were offering an ideal model. The resistance values determined at the six positions (designated $R_1$ through $R_6$) are linked through four formulae to the true resistance at “infinite distance” (i.e., if it were possible to measure the planet as a whole), as follows:

(a)$R_\infty = -0.1187 R_1 - 0.4667 R_2 + 1.9816 R_3 - 0.3961 R_6$

(b)$R_\infty = -2.6108 R_2 + 4.0508 R_3 - 0.1626 R_4 - 0.2774 R_6$

(c)$R_\infty = -1.8871 R_2 + 1.1148 R_3 + 3.6837 R_4 - 1.9114 R_5$

(d)$R_\infty = -6.5225 R_3 + 13.6816 R_4 - 6.8803 R_5 + 0.7210 R_6$

It is expected (and hoped!) that these four calculated resistances will essentially agree and can then be averaged to produce the final test result. Because of the underlying assumptions in the theory upon which the method is based it may happen that the calculation resulting from equation (a) may not be in agreement. If so, it can simply be disregarded and the average taken on the remaining three. Because of the number of variables involved and the enormous range of possible soil resistivities, it would be a prohibitive task to try to scientifically define “essential agreement.” For practical fieldwork, the operator’s work experience is always an essential ingredient. Familiarity with the procedure can be counted on to develop a sense of when it’s working and when it’s not.

There still may remain a complication based on distance to the current probe. In order for all of the underlying assumptions to be valid, the theory behind four potential still requires a fairly long lead length to the current probe. For typical larger substations, or those with exceptionally low ground resistances, these lengths can run to 1000 or 2000 feet! This may not be possible, yet if not achieved, the resultant equations will fail to produce satisfactory agreement. All has not been lost, however! Failure of agreement at least informs the operator that a valid test has not been made. Some time has been expended, with the mathematical test “proofing” the result, whether acceptable or not. In the latter case, the test can be repeated using an alternate method that can be successfully accomplished with shorter lead lengths. Favorites in such instances are the slope and intersecting curves methods, which have been described in earlier columns.

The theory upon which the four potential method is based is complicated, relying heavily on mathematical derivation and assumptions about the shape of the test electrode’s electrical field. It will be explored in more detail in a future column.

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**Reference**

Paper 4619S from the proceedings of the IEE vol. III, No. 12, Dec. 1964 by Dr. G. F. Tagg.

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