Analysis On The Factors Affecting Resistance Of The Earth Electrode

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ABSTRACT

This paper deals briefly with the most important aspects of the resistance of electrodes used for earthing electrical Installations After comparing details are given of the resistivity of the soil and the size and lay-out of electrodes on their resistance. It is shown that in order to have a low resistance the electrodes should cover a large area by consisting of either strips or, alternatively, a number of small electrodes connected in parallel. To facilitate the latter arrangement it is recommended that driven rod or pipe electrodes be used. A low resistance may also be obtained by salting the soil around electrodes, and this is considered together with the effect of using coke breeze. In some cases, however, the nature of the ground fault may be such that it makes non effective earth connection.

Keywords: Power System, Protection,, Selectivity

(1) INTRODUCTION

The study is a comparative analysis of a variety of grounding electrode types. A major requirement of the test program is identical grounding electrodes are installed in tests beds of varying soil mediations and in multiple site locations. In each geographical location identical sets of electrodes are to be installed. The predominance of the electrodes could then be compared to each other. The test sites we picked based on a limited amount of knowledge of soil types and soil resistivity within the Las Vegas Valley and included areas within local municipalities. Soil resistivity d in for Utility Substations were available from the Utility Company and a soil's type map was available from Clark county .From this information an attempt was made to get a mixture of soil types and resistivity to use for the test sites. Also, if necessary, to study under fault conditions the voltage gradient in the ground near the earth plate with various types of soil.

A preliminary survey of the subject indicated that a study of the earth electrode itself was of primary importance, and that the question of the methods of earthing the neutral point and methods of earthing for the protection of personnel should be left until later. (The term "earth electrode" is used rather than "earth plate" to indicate the body buried in the earth, whether it be a plate, pipe, strip, or any other piece of metal used to conduct current from the earthing system to the earth.) This paper is therefore restricted to a consideration of the resistance of earth electrodes. Later reports will deal with the loading capacity of electrodes, the voltage distribution in the soil around them under fault conditions, the mechanical details of their installation and construction, and the use of earthing and earth electrodes for various purposes.

(2) TYPES OF ELECTRODES IN USE.

Earth electrodes may be divided into two classes—those which are used as earth electrodes only, and those which are primarily used for some other purpose. The first class comprises plates, strips, pipes, rods, and all kinds of specially designed electrodes. The second class comprises water pipes, frameworks of buildings, well linings, and cable armouring. Of this class, water-pipe earths are the most common, and in this country it is customary to make use of the circulating water-pipe system in power stations. Water-pipe systems are very Frequently used in earthing house and building installations. Generally speaking, such earths are of low resistance and, from an electrical point of view, are very satisfactory. The following conclusions, based on information obtained from 30 of the largest supply undertakings in the country, have been reached with regard to the British practice of power station and substation earthing:

(a) The earth plate is the most usual type of electrode.
(b) There is no clear preference for either iron or copper plates.
(c) Buried pipes are more usual than plates at generating stations, but less usual at substations.
(d) Plates or pipes are almost invariably buried in coke or carbon or a mixture of these with soil.
(e) Some arrangement is generally made for keeping the ground moist around the electrode.
(/) Where a number of plates or pipes constitute an earth they are usually buried close together

On these conclusions the following comments may be made.
(i) The use of earth plates involves making a connection underground, and corrosion is thereby liable to cause an undetected discontinuity of the connecting conductor. This is particularly liable to occur if the plate and conductor are of dissimilar metals.
(ii) It appears to be thought that the resistance of an earth varies inversely as the surface area of the electrode. I t is not realized that two pipes or plates have half the resistance of one, only if they are spaced something over 6 ft. apart. Any given set of pipes or plates, therefore, may have a much larger resistance than it would if the pipes or plates were buried at the correct spacing.
(iii) The function of the coke breeze or charcoal is imperfectly understood. The resistance of coke or charcoal is so low compared with that of soil that its effect is virtually to increase the size of the electrode to that of the pit. The decrease of resistance by putting several electrodes in one pit is, therefore, only due to the increase of area of contact of the soil and coke or charcoal.
(iv) Some varieties of coke are known to cause corrosion of copper.
(v) Some of the earths constructed must be very costly in labour, coke, and material. A lower-resistance earth obtained from driven pipes or rods or buried strips could be constructed for a fraction of the cost.

(3) REQUIREMENT

It can be a very complicated task to design a grounding system with any degree of certainty. Much of the infbnnation a design professional would use is abstract or condensed from other sources. Engineers are required to forecast the performance of grounding electrodes without cornplete information on the capabilities of these systems and in many cases with incomplete knowledge of site conditions such as soils resistivity. The available resource material is based on different study models and separate studies in different soils. 250 specifies minimum installation criterion for ground electrodes. These NEC minimum are for the most part prescriptive requirements that would allow the installation of a specific electrode in a given design and do not contain performance objectives such as a 25-ohm resistance minimum. Many systems are installed where the performance of the electrode is actually unknown. Currently, the National Electrical Code (NEC) in Article

(4)FACTORS AFFECTING THE RESISTANCE OF ELECTRODES.

(a) Resistivity of the Soil.

The resistivity of the soil is the most important factor affecting the resistance of an electrode. Excluding mineral deposits, it may vary from a few hundred ohms to 106 ohms per cm cube, although most soil falls within the range 500-50 000 ohms per cm cube.
The conductivity of any soil depends on the following factors:—
Type of soil.
Chemical composition of salts dissolved in the contained water.
Concentration of salts dissolved in the contained water.
Moisture content.
Temperature.
Grain size of the material and distribution of grain size.
Closeness of packing, and pressure.
Two of these factors, viz. the moisture content and the temperature of the soil, vary with the seasons and give rise to a periodic change in the resistance of electrodes. Temperature variations above freezing point are of small moment, but moisture variations may convert an excellent earth connection into a useless one during a prolonged dry period. Such an occurrence must be guarded against by regular resistance measurements and watering of salting, if necessary.

(b) Effect of Shape, Spacing, Number, and Size of Electrodes.

The shape of an electrode exercises a material influence on its resistance .For a given area the more extensive the electrode the lower the resistance. Thus a rod 10 ft. long and 1 in. diameter has a lower resistance than one 5 ft. long and 1-41 in. diameter, or a plate 10 ft. long by 1 ft. wide has a lower resistance than one 4 ft. long by 2 | ft. wide. Similarly, if the plate is extended until it becomes a strip 100 ft. long by 0-1 ft. wide, it will have a very much lower resistance than the plate 4 ft. by *2* ft., although the surface area is the same in the two cases. The resistance of electrodes is mainly in the soil within a few feet of their surface, and this resistance area should be as large as possible. It therefore follows that when a number of electrodes are connected in parallel they should be spaced as far apart as possible. Pipes or rods should, where possible, be at least 6 ft. apart in order that their resistance areas do not overlap. Plates and strips should be similarly treated. The best way of making the area covered by the electrodes as large as possible is to install a large number of small electrodes rather than a small number of large ones, and installation cost per electrode therefore becomes of considerable importance. The cheapest electrode to install is the driven rod or pipe, which should be about 6 ft. long, and, wherever the ground is of such a nature as to permit driving, it is recommended that these electrodes be used at a spacing of not less than 6 ft. in general. If, however, the ground area available is restricted it may be necessary to use a smaller spacing or longer electrodes. It may even be necessary to treat the electrodes with salt to obtain a sufficiently low resistance. Extensive electrodes such as water mains and cable sheaths should be used wherever possible in conjunction with other electrodes, since their resistance is usually very low. On account of the risk of electrolysis it is preferable not to use them on d.c. circuits, and,-furthermore, on account of their limited cross-sectional area they should not be used where the fault current would be sufficiently high to cause overheating of the lead sheath or iron pipe. Published information does not indicate that special and patented earth electrodes are in any way better than simple rod or pipe electrodes. Some of these are claimed to absorb moisture in wet periods and give it out again in dry periods, but there is evidence that even if such effects do take place they have negligible effect on the seasonal variation of resistance.

(c) Artificial Treatment of Soil.

The mixing of coke breeze and soil or the replacement of the soil around an electrode by coke breeze, reduces the resistance of the electrode, but the method is expensive to apply and may accelerate corrosion. Tests are being made by the E.R.A. to determine the effect of this method of treatment. An alternative method of reducing the resistivity of the soil around an electrode is to treat it with common salt. By this means, in certain tests conducted by the E.R.A. the resistance of a 6 ft. driven pipe was reduced by 85 per cent with 100 lb. of salt. Salt treatment is not permanent, but replenishment is necessary much less frequently than is usually anticipated. Once a year would meet almost all cases, and in some soils once in three years would suffice.

(5)CONCLUSION AND RECOMMENDATIONS.

The engineer's problem in designing an earth connection is, in the first place, to determine what value of resistance is required and, in the second place, to decide how this value of resistance may be obtained. The value of the resistance is controlled by one or more of the following factors:—

(a) The operation of protective gear in the event of an earth fault.

(b) The prevention of a dangerous contact voltage occurring between the earthed metal work and any other point within reach at earth potential, when the Maximum fault current is flowing; the maximum fault current being the current which just fails to operate the protective gear.

(c) The prevention of drying-out of the soil due to the flow of current.

The resistance necessary to satisfy the first condition may be readily determined from the details of the protective gear. The above factor depends on the value of dangerous voltage which is assumed. This. question will be considered fully in a later report. For the present it must suffice to state that after a careful analysis Feraud gives the maximum non-dangerous voltage as 30 volts, but the value to be used depends on whether the conditions are damp or dry. The third factor does not often have to be considered, and at the moment*no recommendations can be made on current-carrying capacity; an E.R.A. report on the subject will shortly be issued. Having decided on the value of resistance required, it is necessary to design the electrode so that this value may be obtained. The design depends on the space available, the nature of the soil, and the resistivity of the soil under the driest conditions. The resistivity may be measured *in situ* by an instrument such as the" Megger " earth tester, or by taking samples.* If the measurements are not made in a dry season, a certain amount of estimation is necessary. If the space is small for the resistance required, or if a rock stratum occurs at a small depth, copper or galvanized iron strips about 1 in. x £ in. buried horizontally in a straight line (or radially from a point) at a depth of 2-3 ft. are recommended. Such a strip, 10 ft. long, has a resistance of about 40 ohms, and one 100 ft. long about 6 ohms, in soil having a resistivity of 10 000 ohms per cm cube. For general use where the space is not confined, 1-in. diameter pipes (or rather smaller diameter rods, say, £ in.) driven 6 ft. into the ground are recommended. Such an electrode has a resistance of rather less than 50 ohms in soil having a resistivity of 10000 ohms per cm cube. Two in parallel, if spaced not less than 6 to 8 ft. apart, have a resistance of about 60 per cent of one, and three have a resistance of about 45 per cent. Probably the resistance of any number of pipes in parallel and 6 ft. apart, arranged in a straight line or a circle, is not more than 1*5 times the value calculated from the formula for resistances in parallel. Where the space available is very restricted or the resistivity very high, the electrodes should be treated periodically with common salt to reduce this resistance. Sufficient information is not yet available to permit a definite recommendation to be made either for or against the use of coke breeze. Tests are, however, now being conducted by the E.R.A. to compare strip, pipe, and plate electrodes, buried direct in soil, with similar electrodes surrounded by a bed of coke breeze.

The following are the detailed conclusions reached in regard to factors affecting the resistance of electrodes, and the recommendations made for the improvement of practice.

(1) The resistance of an electrode depends considerably on the type of soil in which it is buried. Where there is any option the type should be chosen in accordance with the following list, in which the various types of soil are arranged in ascending order of resistivity:—

(i) Wet marshy ground and ground containing refuse such as ashes, cinders, and brine waste,
(ii) Clay, loamy soil, arable land, clayey soil, and clayey soil or loam mixed with small quantities of sand,
(iii) Clay and loam mixed with varying proportions of sand, gravel, and stones,
(iv) Damp and wet sand, peat,
(v) Dry sand,
(vi) Gravel and stones.

The resistivity of the second class of material is about twice that of the first, which may be taken as not more than 1 000 ohms per cm cube, and that of the last varies from 20 to 40 times that of the first.

(2) The seasonal change of resistance of salted electrodes is very much less than that of unsalted ones.

(3) The seasonal change of resistance of short pipes or rods (say, 2 ft. or less) makes them quite useless as earth electrodes unless they are artificially treated.

(4) A reduction of resistance of electrodes occurs very quickly after rainfall, but soon wears off with electrodes which do not extend more than 2 or 3 ft. below the surface.

(5) Pipes and rods extending to a depth of 6 ft. or more are not much affected by seasonal changes.

(6) In general, there is no justification for the use of special and patented electrodes.

(7) Regular measurements of the resistance of earth electrodes should be made either with an alternating current of several amperes or with some form of earth-resistance tester. Records should be kept of the results.

REFERENCES

[l.] M. Podboj, J. GoriSek: FPC 500 – Protection, monitoring and control of MV lines; 9'h International Conference on Relay Protection and Local Automation in Electric Power Systems, Ljubljana 1994

[2.] F. Leskovec: Protection Discrimination Between Switching Station 20kV and Substation 110/20kV; **3'd** SLOKO CIGRE Conference, Nova gorica 1997 – **256**

[3.] TAGG, G.F.: 'Earth resistances' (George Newnes, London, 1964)

[4.] TAGG, G.F.: 'Multiple-driven-rod earth connection', IEE Proc. C,Gen., Trans. & Distrib.,1980,