# EARTH RESISTANCE

## INTRODUCTION

Electrical equipment at all voltage levels must be earthed i.e. connected directly to an electrode driven or buried in the ground. The resistance between the earth electrode is critical to the safety of equipment and personnel. Usually it must be less than 100 ohms e.g.. 10 ohms for an overhead line pylon. This is not always possible because of the high resistivity of some earthy materials.

## THEORY

See 'EHV Transmission Line Reference Book' p.290 and 'Electrical Transmission & Distribution Reference Book' Westinghouse Electric Corporation, Section I pp.570-590.

Single Rods: $R = \rho[\ln(2L/a)-1]/(2\pi L)$

Parallel Rods: $R = \rho[\ln(2L/A)]/(2\pi L)$

Where $L$= length of rod in ground, m, $a$= radius of rod, m
$\rho$= ground resistivity, ohm-m

$A = \text{sqrt}(aS)$

$S$= separation, m

## APPARATUS

YEW Earth Tester TYPE 3235 (L-91)
100' metal tape measure
Earth rod
Sledge hammer & crow bar

## METHOD

1. Select an existing earth electrode or drive the earth rod into the ground to be measured ensuring that there is at least 40-50 m of open ground adjacent to the electrode.
2. Connect the earth tester as shown in FIG.5
3. Position Electrodes P and C at L= 5m, carry out a trial measurement. Adjust the dial and momentarily depress the push-button. If the needle is off-scale, adjust the dial again and depress the push-button momentarily. Repeat this until the pointer remains on scale. The push-button can then be held down whilst the dial is adjusted to give a central reading of the pointer
4. Take a series of readings by varying L. Plot a curve of R against L. Determine the optimum value of L.
5. Drive a second earth rod 1m from the earth. Measure its resistance for the optimum value of L, the length L, and the radius a

6. Connect the two earth rods together and measure there combined resistance at the optimum value of L.

## RESULTS:

1. Plot the results of step 4 on graph paper
2. Calculate ρ from the results of step 5.
3. Tabulate the resistance values.
4. Calculate the value of two rods in parallel.

## DISCUSSION:

Compare the experimental curve with the expected theoretical curve. Is the manufacturer's range for L reasonable? What was your optimum value of L? Compare the measured & calculated values for the rods in parallel.

## CONCLUSIONS:

1. How can the earth resistance be reduced?
2. Was the soil tested a good earthing material?
3. What is achieved by connecting rods in parallel?

Read the following notes on ground resistance

## GROUND RESISTANCE

An understanding of the basic aspects of tower footing resistance characteristics and measurements is very useful in evaluating the lightning performance. The resistance of a rod electrode of length 2l and diameter 2a buried at an extreme depth in the earth is given by

$$R = \frac{\rho \ln (2l/a)}{4 \pi l}$$

where ρ is the ground resistivity.

If this electrode is buried with only half its vertical dimension in earth, the resistance will be twice that given in the above expression. The resistance will be only somewhat less than twice that given above if the electrode is buried at a depth small in comparison to the length dimension.
The most useful form of the ground electrode is the driven ground. Ground rods are usually supplied in-3 - 4.5m's in length and may be joined by couplings for longer depths. Rod diameters are generally less than 2.4 cm. The resistance of a driven ground rod in ohms is:

$$R = \frac{\rho \,[\ln (2l/a) - 1]}{2\pi l}$$

where ρ = ground resistivity, ohm-m
l = length of rod, m
a = rod radius, m

The diameter of the rod is of less significance since it affects only the logarithmic term 2l/a, but the length is very important.
The resistance does not decrease directly with length, however, and a condition can arise when further increase in length is accompanied by only a minor reduction in footing resistance.

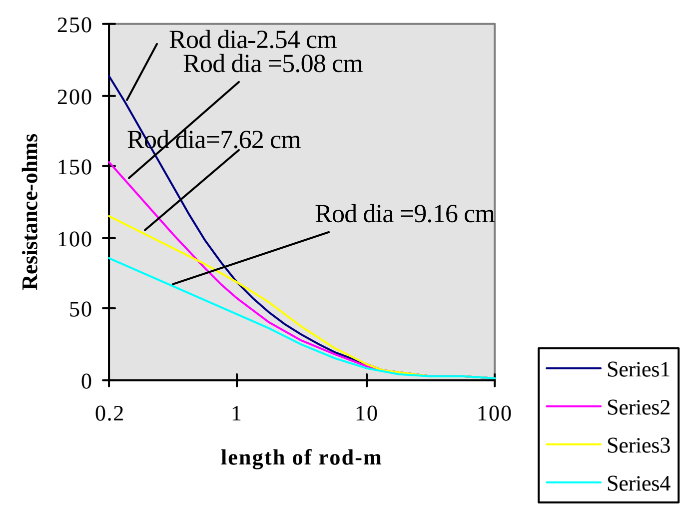



**Fig1.Resistane of vertical ground rods as a function of length and diameter-soil resistivity=100 m-ohms**

Fig. 1 shows the variation of resistance with rod length for various diameters. The curves are drawn for a ground resistivity of 100 ohm-m.

Connecting driven ground rods in parallel can also lower ground resistance. If the spacing between rods is large compared to the length of the individual rods, the resistance will be reduced in proportion to the number of rods. If the rods are close together, each rod will be in the intense electrical field of its neighbour. If the rods are very close together, the over-all resistance becomes

$$R = \frac{\rho \ln (2l/A)}{2\pi l}$$

where A represents the resistance of an equivalent rod. Fig. 2 shows how the equivalent radius depends on rod geometry. If the rods are moderately close to each other, the over-all resistance will be more than if the same number of rods was spaced far apart. The increase in resistance depends on the number of rods involved
The fundamental method of measurement of ground resistance is shown in Fig.3. Current is circulated between the ground under test and an auxiliary ground. This should be preferably located at a distance that is large compared to the dimensions of the ground under test since it is not desirable to have interaction of the ground current distributions at the two electrodes. A voltage is then measured between the ground under test and a reference ground located somewhere between the two current carrying electrodes. This reference ground should also be so located that it is not in the electric field of either the current carrying electrodes. Assuming that the current density is negligible at the reference electrode, the resistance of the ground under test is R = V/I. The measurement may be made by using a voltmeter and ammeter with

the current being supplied from the AC power lines. Alternatively, a bridge may be used for measurement. Most often, the ground resistance is measured with self-contained instruments such as the Megger ground resistance Tester.
The resistivity of earth may vary over extremely wide limits, depending on the composition of the soil and the moisture content. Representative values are:

| | |
|---|---|
| General average | 100 ohm-meters |
| Swampy ground | 10-100 ohm-meters |
| Sea water | 0.01-1 ohm-meters |
| Dry earth | 1000 ohm-meters |
| Pure slate | $10^7$ ohm-meters |
| Sandstone | $10^8$ ohm-meters |

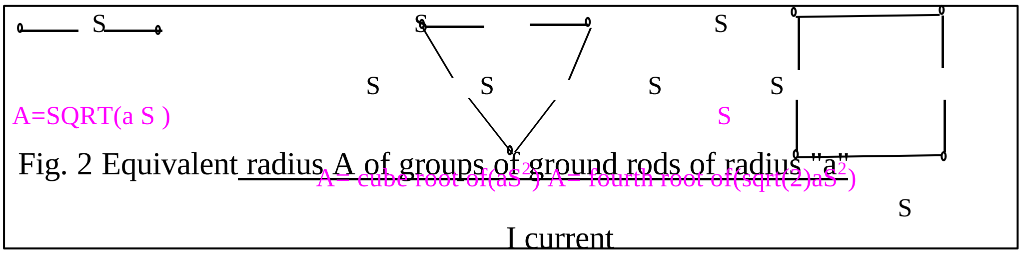



Fig. 2 Equivalent radius A of groups of ground rods of radius "a"

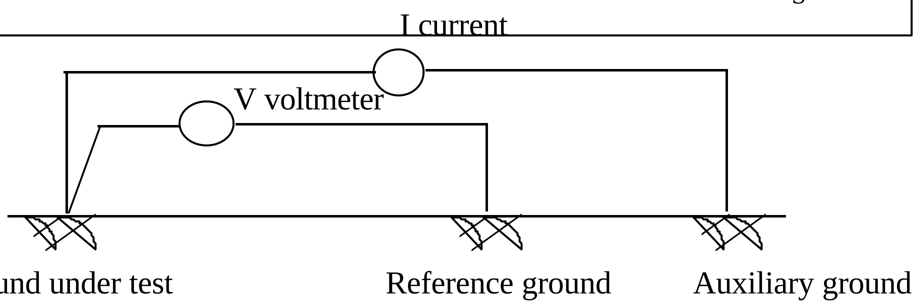



Fig. 3 Fundamental method of ground resistance measurement

## TYPE 3235 Earth TESTER

Adequate earthing systems for telecommunications, electronic and electrical equipment, power lines and lightning arresters of steel towers and high buildings are of extreme importance. Good earthing systems safeguard personnel and equipment during fault conditions. They are also frequently necessary in minimising electrical noise and for normal, reliable operation of electrical and electronic equipment. The resistance of any earthing system should be periodically checked to ensure that it is within limits.
The Type 3235 Earth Tester can be used to check almost any earthing system. It incorporates a test for earth voltage. AC voltage up to 30V may be measured. High

earth voltages indicate either high earth currents (due to equipment faults) or a faulty earthing system. High earth voltages indicate a condition that may be dangerous.
Its 3-electrode earth resistance measurement uses an AC potentiometer bridge. Two earth electrodes are used besides the system earth under test.
Test electrode resistance is not critical, up to 10 k-ohms is tolerable; or a single "good "earth test electrode is such as a metal water pipe may be used for 2-electrode measurements.
The AC bridge uses a transistorised 500 Hz inverter and synchronous detector, so is not affected by the normal DC or 50/60 Hz earth voltages of normal equipments. Bridge balance is indicated by a rugged but sensitive taut-band suspension galvanometer.

Measuring range:

Earth resistance: 0 to 10 to 100 to 1000 ohms
Earth voltage: 0 to 30 v AC
Measuring frequency:

500 Hz

Measuring current:

Up to 20 mA 500 Hz)

Power source:

Four 1.5 V dry cells

Names and functions of components:

1. Measuring terminals

E (system earth under test)
P and C (earth test electrodes)
E and P terminals are used to measure earth voltage.
E, P and C to measure system earth resistance
Dial scale: 0 to 1000 ohms

3. Indicator:

displays tester internal battery or system earth voltages, or indicates earth resistance bridge balance
4. Push - button switch

Enables internal battery check and resistance measurement ranges. Must not be operated during system earth voltage measurement.

5. Selector switch - measuring modes.

Ω- system earth resistance

V- system earth voltage
B-battery voltage check

6. Index

## OPERATING INSTRUCTIONS

### Electrode connections

a) E is the system earth under test. P earth test electrode is the centre point of the resistance bridge, and is also used for earth voltage tests. C electrode supplies current to the Resistance Bridge. Fig 5) l should be at least 5 to 10 meters,
E, P, C should lie in a straight line approximately, and earth resistance of the test electrode should be low.

### Practical considerations

There are often problems in siting suitable test earths, especially where system earth is in a building surrounded by pavements and other buildings. Ground near tree or in garden plots (where not above asphalt or concrete paving), water pipes (where plumbing is all - metal and not internally insulated by carbonate deposits from hard water) and manholes in building basements may provide access to suitable test earths.
EP should approximately equal PC

### Principle of measurement

Fig. 6

System earth resistance Rx
Measuring current I

When the bridge is balanced (Galvanometer current is zero) voltage across Rx is

Ex = Ep = Eso........(1)

Ex = I Rx....(2)

Since Eso = nI Rso
I Rx = nI Rso
Therefore,

Rx = n Rso.... (3)
According to equation 3, the log dial scale of potentiometer is calibrated a to show a value n Rso corresponding to Rx.

### Measurement of earth resistance

(a) Suppose that the electrodes E and C are connected to source as in Fig.7 (a). P. D between E and C is shown in Fig. 7 (b) or (c). If EC is great enough l1, an equivalent area appears midway between E and C so that Ex (voltage drop by Rx) may easily be distinguished from Ec (volt drop by Rc). Therefore, if another electrode P is buried midway between E and C,

Ex = I. Rx.

Therefore Rx = Ex/I.... (4)

(b) If EC is sufficient l2, the equipotential area does not appear at all as in Fig 7(c). Because of this it is impossible to distinguish Rx from Rc. Generally a suitable distance EC is 10 to 20 m.

Fig 7

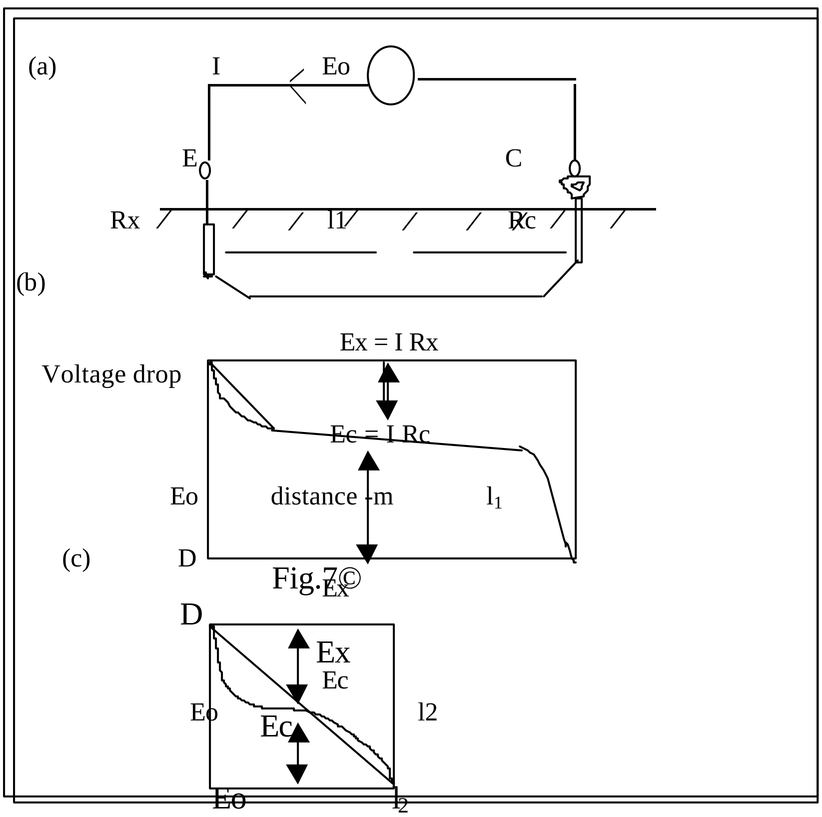



Fig. 6

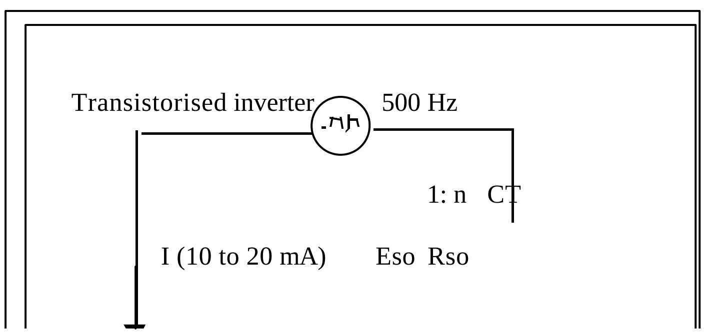
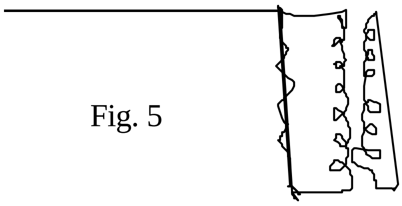


Fig. 5



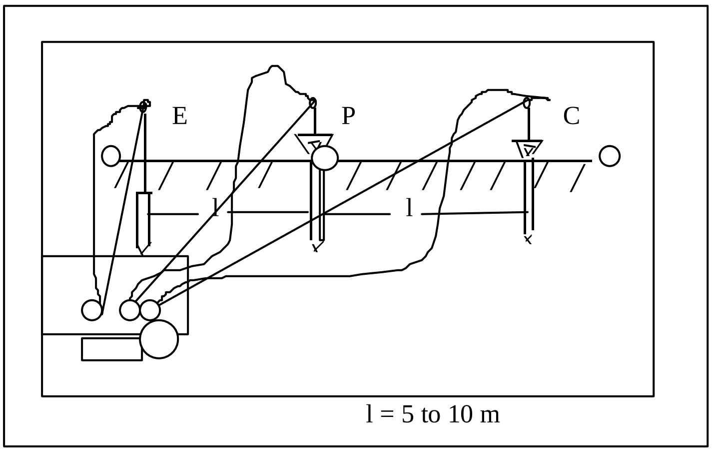



Fig. 4