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Power Systems Analysis and Design (BR Gupta)
Power Systems Earthing
Problems 1 - 4.

Problem 1:

a). Find the earth resistance of a driven rod of length 3m and diameter 2cm, if soil resistivity is 60 ohm-m.

b). Find the radius of a hemispherical electrode which has the same resistance as the above driven rod.

Solution:
a).

$Rod_{len1} := 3\ \mathbf{m}$ $Rod_{dia} := 0.02\ \mathbf{m}$ $\rho_{soil1} := 60\ \mathbf{ohm} \cdot \mathbf{m}$

$$R := \frac{\rho_{soil1}}{2 \cdot \pi \cdot Rod_{len1}} \cdot \ln\left(\frac{4 \cdot Rod_{len1}}{Rod_{dia}}\right)$$

$R = 20.362\ \Omega$ This is not the ohmic resistance of the electrode but represent the of the mass of earth surrounding the earth electrode (ie ground rod)

b).

R = p / (2 pi B)

$$B_1 := \frac{\rho_{soil1}}{(2 \cdot \pi \cdot R)}$$

$B_1 = 0.469\ \mathbf{m}$ Radius of the hemisphere

Problem 2:

a). Find the resistance of two driven rods each of length 3m, and diameter 2cm, and buried in a soil of resistivity 60 ohm-m (clay soil). Spacing between the rods is 3m.

b). Find resistance of 3 such rods arranged in a straight line, with 3m spacing between adjacent rods.

c). Find the resistance of three such rods arranged in an equilateral triangle with 3m side.

d). Find the resistance of four rods arranged at the corners of a square of side 3m

Solution:
Using the results of Problem 1.
See the value of resistance decreasing with more parallel rods,
and proximity of rods or configuration (triangle, square, etc)

a).

$$\alpha := \frac{B_1}{Rod_{len1}} \qquad \alpha = 0.156$$

$$R_2 := R \cdot \left(\frac{1+\alpha}{2}\right)$$

$R_2 = 11.773\ \Omega$ 2 rods in parallel

b).

$$R_3 := \frac{R \cdot \left(2 + \alpha - 4 \cdot \alpha^2\right)}{6 - 7 \cdot \alpha}$$

$R_3 = 8.544\ \Omega$ 3 rods in parallel

c).

$$R_{3\_tri} := R \cdot \left(\frac{1 + 2 \cdot \alpha}{3}\right)$$

$R_{3\_tri} = 8.909\ \Omega$ 3 rods in an equilateral triangle

d).

$$R_{4\_sqr} := R \cdot \left(\frac{1 + 2.707 \cdot \alpha}{4}\right)$$

$R_{4\_sqr} = 7.245\ \Omega$ 4 rods in a square

Problem 3:

A wire of length 3m and radius 0.25cm is buried in a soil of resistivity 100 ohm-m (sandy clay mixture soil).
Find the earthing resistance when
a). wire is buried at surface of earth
b). wire is buried at 0.5m depth
c). wire is buried at infinite depth

Solution:

$Rod_{len3} := 3\ \mathbf{m}$ $\quad Rod_{dia3} := 0.0025\ \mathbf{m}$ $\quad \rho_{soil3} := 100\ \mathbf{ohm \cdot m}$

a).

$$R_{surface} := \left(\frac{\rho_{soil3}}{\pi \cdot Rod_{len3}}\right) \cdot \left(\ln\left(\frac{2 \cdot Rod_{len3}}{Rod_{dia3}}\right) - 1\right)$$

$R_{surface} = 71.972\ \Omega$

b).

$h_3 := 0.5\ \mathbf{m}$

$$R_{h05m} := \left(\frac{\rho_{soil3}}{\pi \cdot Rod_{len3}}\right) \cdot \left(\ln\left(2 \cdot \frac{Rod_{len3}}{\sqrt{2 \cdot Rod_{dia3} \cdot h_3}}\right) - 1\right)$$

$R_{h05m} = 40.187\ \Omega$

c).

When cable is buried at infinite depth, the resistance is half of the value at surface

$$R_{infinite3} := \frac{R_{surface}}{2}$$

$R_{infinite3} = 35.986\ \Omega$

Note: The resistance keeps decreasing as the depth increases.

Problem 4:

Concrete encased electrodes (ground rod).

General Notes:

1. concrete is hygroscopic (absorbs moisture)
2. buried n earth it behaves as a semiconducting medium
3. resistivity of 30-90 Ohm-m
4. in medium and high restivity soil an electrode buried in concrete has a lower resistance than that of a similar electrode directly buried in earth
5. splitting of concrete may occur due to corrosion
6. passage of high fault current may vaporise the moisture in the concrete leading to splitting
7. it should be used in conjunction with a grid mesh or earthing system, so as to split the high fault current, lessening the cause for splitting
8. it requires proper installation method (making the concrete shell, fitting the electrode in it , and proper connection point, etc)

Find the earthing resistance of a concrete encased electrode:
Given the following data:
pc Resistivity of concrete - 75 ohm-m
ps Resistivity of soil - 100 ohm-m (sandy clay)
l Length of electrode - 3m
d Diameter of electrode - 2cm
D Diameter of concrete shell - 20cm

$\rho_{conc} := 75\ \mathbf{ohm \cdot m}$

$\rho_s := 100\ \mathbf{ohm \cdot m}$

$l := 3\ \mathbf{m}$

$d := 0.02\ \mathbf{m}$

$D := 0.2\ \mathbf{m}$

$$R_{cEnc\_rod} := \frac{1}{2 \cdot \pi \cdot l} \cdot \left(\rho_{conc} \cdot \ln\left(\frac{D}{d}\right) + \rho_s \cdot \left(\ln\left(\frac{8 \cdot l}{D} - 1\right)\right)\right)$$

$R_{cEnc\_rod} = 34.516\ \Omega$ This resistance is lower compared to almost similar installation conditions in previous problems.