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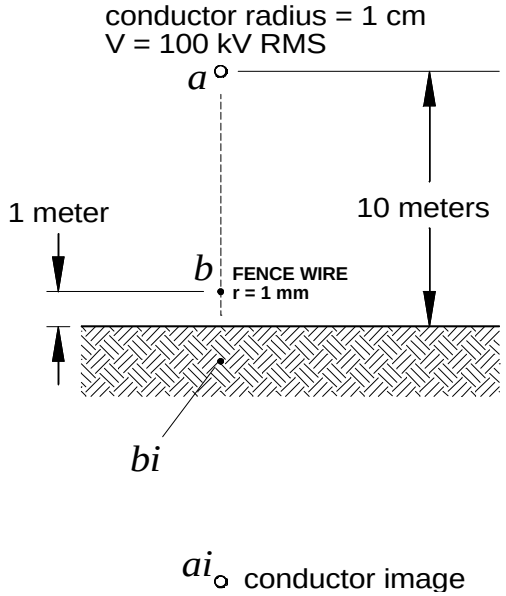
EE368 Electrical Power Transmission and Distribution
Homework 5, 2/20/99

Problem:

Given a single conductor 10 meters above ground with a radius of 1 cm carrying a voltage of 100 kV_{RMS}, and a fence wire directly below running parallel to the transmission line 1 meter above the ground, insulated from ground, having a radius of 1 mm: How long must the fence be in order to present a 1 mA shock hazard? Assume a person has a resistance of 1300Ω.



Matlab Program:

```
% *************  GIVEN VALUES  ***************************************

format short                % Instruction to display 5-digit results
LineVoltage = 100000        % Line Voltage RMS
Frequency = 60              % Line Frequency [Hz]
LineHeight = 10;            % Line height above ground [meters]

FenceHeight = 1;            % Height above ground of test area [meters]
LineRadius = .01            % Conductor Radius [meters]
FenceRadius = .001          % Radius of the fence wire
Rperson = 1300              % Resistance in a person [ohms]


% **********  ADDITIONAL VARIABLES  **********************************

Q = [];                     % Charge matrix [C/m]
Volts = [];                 % Voltage matrix [V]
Capacitance = [];           % Capacitance matrix
Dab = 0;                    % Distance from line to fence [meters]

Dbai = 0;                   % Distance from line image to fence [meters]
FenceVoltage = 0;           % Voltage on the fence [volts]
FenceLength = 0;            % Length of fence [meters]
FenceCurrent = 0;           % Current in the fence [amps/meter]

Omega = Frequency*2*pi;     % Frequency [radians per second]
```

```
% ************  CUSTOM FUNCTION  ************************************

% Cap(Line to Image Distance in meters,Radius or Line to Line distance
% in meters)
% Returns the capacitance per meter for power lines in air
% function Result = Cap(A,B);
% Result = 2*pi*8.85*10^(-12)/log(2*A/B);


% ************  CALCULATE CAPACITANCE AND CHARGE  *********************

Dab = LineHeight-FenceHeight; Dbai = LineHeight+FenceHeight;
FenceVoltage = LineVoltage * log(Dbai/Dab) / log(2*LineHeight/LineRadius)
Capacitance = [Cap(2*LineHeight,LineRadius) Cap(Dbai,Dab); Cap(Dbai,Dab)
  Cap(2*FenceHeight,FenceRadius)]
FenceCurrent = FenceVoltage/(1/(j*Omega*Capacitance(2,2))+Rperson)
MagnitudeOfCurrent = abs(FenceCurrent)
FenceLength = 0.1/CP2MP(FenceCurrent)


% *****  CREATE PLOT FOR CURRENT LEVEL RELATIVE TO FENCE LOCATION  ****

Width = 1200; Height = 900; x = []; y = []; Xn = -100;
H = figure('Position',[20 20 Width Height],'Color',[1 .6 .9])

for Xn = -100 : .1 : 100                  % Calculate the amperage/km
  Dab2 = (Dab^2 + (Xn*.3048)^2)^.5; Dbai2 = (Dbai^2 + (Xn*.3048)^2)^.5;
  FenceVoltage = LineVoltage*log(Dbai2/Dab2)/log(2*LineHeight/LineRadius);
  FenceCurrent = FenceVoltage/(1/(j*Omega*Capacitance(2,2))+Rperson);
  x = [x Xn]; y = [y CP2MP(FenceCurrent)*1000*1000];  % Append values
end

plot(x,y,'k-'); grid on                   % Plot amps
set(gca,'FontSize',16,'Xcolor','k','Ycolor','k')
title('Shock Hazard for a 1300\Omega Person in mA/km of
  Fence','FontSize',18,'Color',[0 0 0])
xlabel('Horizontal Distance Relative to ROW Centerline in
  Feet','FontSize',16, 'Color',[0 0 0])   % label the x-axis
                                          % label the y-axis
ylabel('Milliamps per Kilometer of Fence','FontSize',16, 'Color',[0 0 0])
```

Formulas Used:

$$C_G = \frac{2\pi\varepsilon_0}{\ln\frac{2h}{r}} \qquad C_{AB} = \frac{2\pi\varepsilon_0}{\ln\frac{D_{ABi}}{D_{AB}}}$$

$$C = \begin{bmatrix} C_{AA} & C_{AB} \\ C_{BA} & C_{BB} \end{bmatrix}$$

$$I_{FENCE} = \frac{V_{FENCE}}{\frac{1}{j\omega C_{FG}} + R_{PERSON}}$$

$$L_{FENCE} = \frac{0.1}{I_{MAGNITUDE}}$$

C_G = conductor to ground capacitance per unit length [F/m]

C_{AB} = conductor *A* to conductor *B* capacitance per unit length [F/m]

ε_0 = Permittivity of free space 8.85×10^{-12} [F/m]

h = height of transmission line [m]

r = radius of the conductor [m]

D_{ABi} = distance from conductor *A* to image of *B* [m]

D_{AB} = distance from conductor *A* to conductor *B* [m]

C_{FG} = fence to ground capacitance [F/m]

Initial Program Output:

LineVoltage = 100000
Frequency = 60
LineRadius = 0.0100
FenceRadius = 1.0000e-003
Rperson = 1300
FenceVoltage = 2.6401e+003
Capacitance = 1.0e-010 *
0.0670 0.6221
0.6221 0.0670
FenceCurrent = 2.1925e-011 +6.6728e-006i
MagnitudeOfCurrent = 6.6728e-006
FenceLength = 1.4986e+004

(Description of variables is on page 1.)

Result:

A fence 15 kilometers long is required to achieve a 0.1 mA current through an individual having a resistance of 1300Ω.

Plot of Shock Hazard Relative to Length and Placement of Fence: