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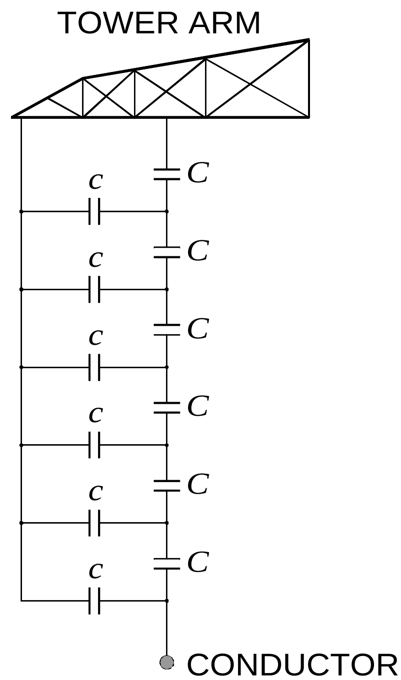
EE368 Electrical Power Transmission and Distribution
Homework 6, 3/5/99



Problem:

Given a single conductor attached to a transmission tower by a six-unit cap-and-pin insulator string, calculate and chart the voltage distribution along the insulator string. Repeat the exercise for 5 different capacitance ratios.

Matlab Program:

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

format short                  % Instruction to display 5-digit results
LineVoltage = 100;            % Line Voltage [%V]
cC = [0 0.1 1/8 1/4 1/2];     % Capacitance ratio c/C
Insulators = 6;               % Number of insulators


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

Vn = 0;                       % Voltage [%V]
Alpha = [];                   % Square root of c/C
x = []; y = [];               % Result matrices, insulators & voltage
A = size(cC,2);               % Number of capacitance ratios to plot
```

```
% **********  FILL ALPHA MATRIX AND 1ST ROWS OF X & Y  ****************

for Cnt = 1:1:A
  Alpha(Cnt) = cC(Cnt)^.5;
  x = [0 x]; y = [0 y];      % Create matrices with 'Insulators' columns
end


% ************  CALCULATE VOLTAGE AT EACH INSULATOR  ******************

for CntA = 1:1:A             % For each value of Alpha
  for Cnt = 1:1:Insulators   % For each insulator
    if Alpha(CntA) == 0      % Prevent divide by zero
      x(Cnt+1,CntA) = Cnt;
      y(Cnt+1,CntA) = LineVoltage*Cnt/Insulators;
    else
      Vn = LineVoltage*(sinh(Alpha(CntA)*Cnt)/
         sinh(Alpha(CntA)*Insulators));
      x(Cnt+1,CntA) = Cnt; y(Cnt+1,CntA) = Vn;   % Fill matrices
    end
  end
end
cC                           % Capacitance Ratios
Alpha                        % Display the Alpha values
x                            % Display x matrix
y                            % Display y matrix


% **************  CREATE VOLTAGE DISTRIBUTION PLOTS  ******************

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

hold on                                      % Plot multiple curves
for CntA = 1:1:A
  % Plot points and curve.
  plot(x(:,CntA),y(:,CntA),'k-',x(:,CntA),y(:,CntA),'ko'); grid on
end
hold off                                     % Finished multiple plots
% Label the Plot:
set(gca,'FontSize',16,'Xcolor','k','Ycolor','k')
set(gca,'ytick',[0:5:100])
title('Voltage Distribution for a Cap-and-Pin Insulator
 String','FontSize',18,'Color',[0 0 0])
xlabel('Insulator Units','FontSize',16, 'Color',[0 0 0])   % label the x-
 axis
ylabel('Percent Line Voltage','FontSize',16, 'Color',[0 0 0])


% ***********************  END OF PROGRAM  *************************
```

Formulas Used:

$\alpha = \sqrt{\frac{c}{C}}$ $V_n = V_g \frac{\sinh \alpha n}{\sinh \alpha z}$	α = capacitance ratio c = capacitance between insulator and tower arm [F] C = capacitance across insulator [F] V_n = voltage between tower arm and insulator unit n [V] V_g = line voltage [V] n = integer value denoting a particular insulator unit. n = 1 is the unit attached at the tower arm z = total number of insulator units

Initial Program Output:

```
cC =         0    0.1000    0.1250    0.2500    0.5000

Alpha =         0    0.3162    0.3536    0.5000    0.7071

x =       0     0     0     0     0
          1     1     1     1     1
          2     2     2     2     2
          3     3     3     3     3
          4     4     4     4     4
          5     5     5     5     5
          6     6     6     6     6

y =           0         0         0         0         0
        16.6667    9.8652    8.7802    5.2017    2.2063
        33.3333   20.7252   18.6694   11.7310    5.5624
        50.0000   33.6750   30.9166   21.2548   11.8175
        66.6667   50.0205   47.0689   36.2039   24.2317
        83.3333   71.4099   69.1663   60.3941   49.2752
       100.0000  100.0000  100.0000  100.0000  100.0000
```

Plot of Voltage at each Insulator: