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Montecarlo method for Insulation Coordination in Power Transmission Lines.

Power Quality Assigment A2

Introduce the simulated problem:

Our goal is to design and selection of insulation materials and protective devices to ensure the reliable and safe operation of the electrical system. In order to prevent electrical breakdown and flashovers that could lead to system failures, damage to equipment, or pose a risk to personnel.

By generating a random map of `10000` lightning hits within an area of `20000mx50000m,` we are going to assess the effect they have in our transmission line.
Our transmission line will be crossing the middle of map from side to side.

By modeling our TOVs, we will assess if the Level of Basic impulse isolation layer (BIL) of our line is sufficient enough to protect us against the effects of lightning hits caused TOVs.

Steps of the Insulation Coordination method:

1. Modelling our lightning map with our transmission line.
2. Modelling each lightning with its current and caused overvoltage in our line. (Direct and indirect strikes)
3. Create our stress curve (up to impulse voltage of 100Kw).
4. Create our isolation curve (also up to 100Kw).
5. Calculate the risk curve from the two previous curve, asses results.

Plots of spatial distribution of lightning strikes, plots of histograms (current, overvoltages) :

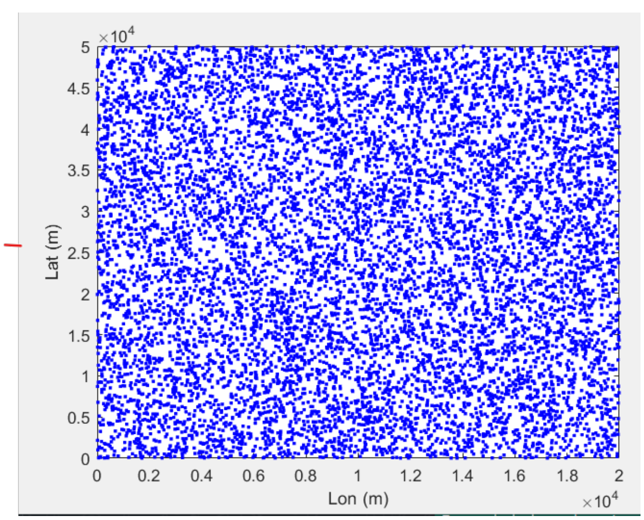

FIGURE 1, SPATIAL DISTRIBUTION OF LIGHTNING STRIKES

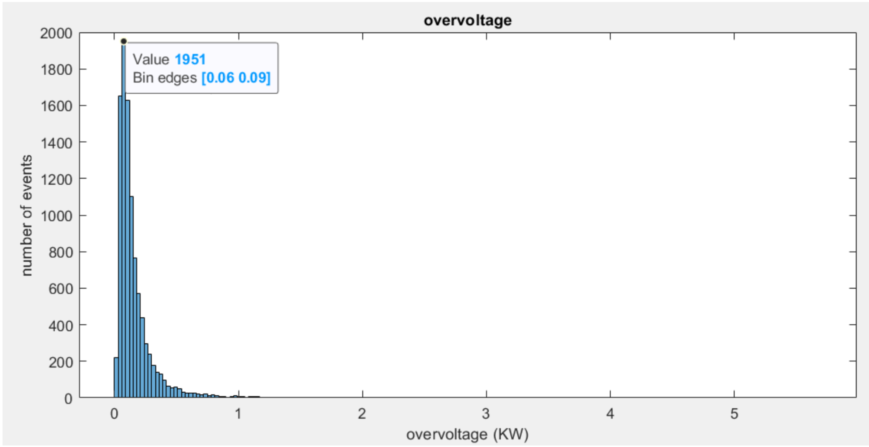

FIGURE 2, OVERVOLTAGE HISTOGRAM (KV)

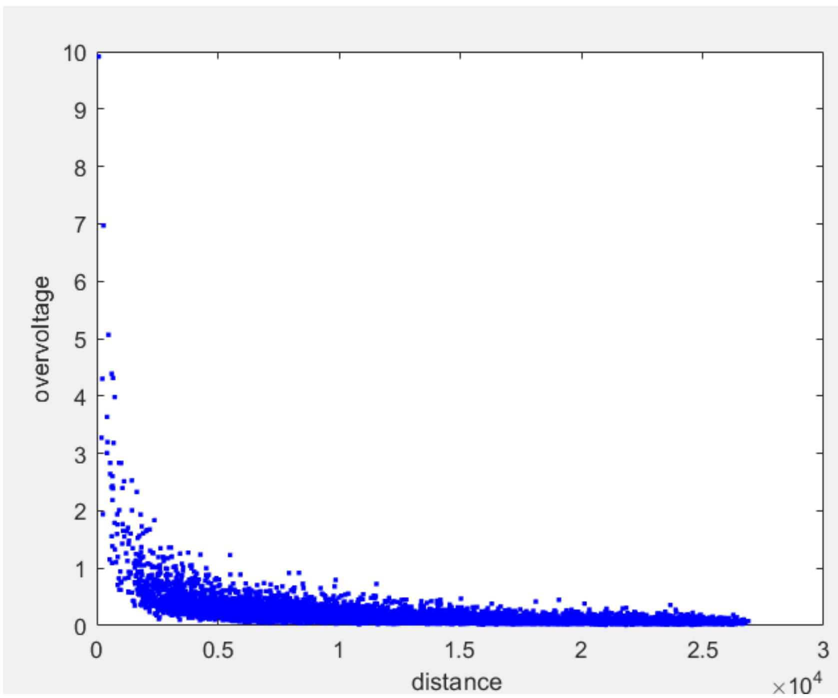

FIGURE 3, OVERVOLTAGE RELATED TO DISTANCE OF EACH LIGHTNING TO THE LINE

The median value for overvoltage is 0.1107 KV

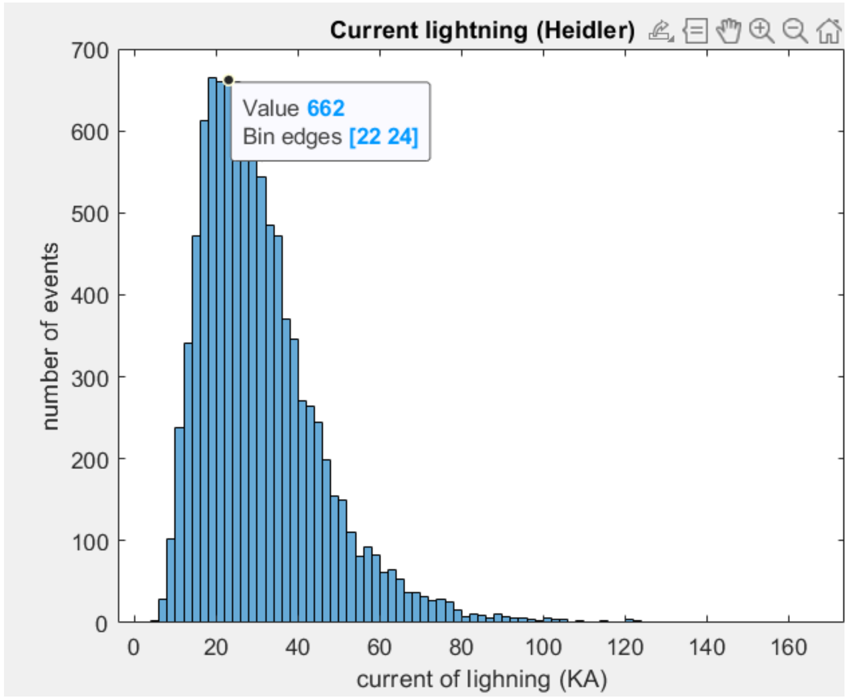

FIGURE 4, CURRENT HISTOGRAM

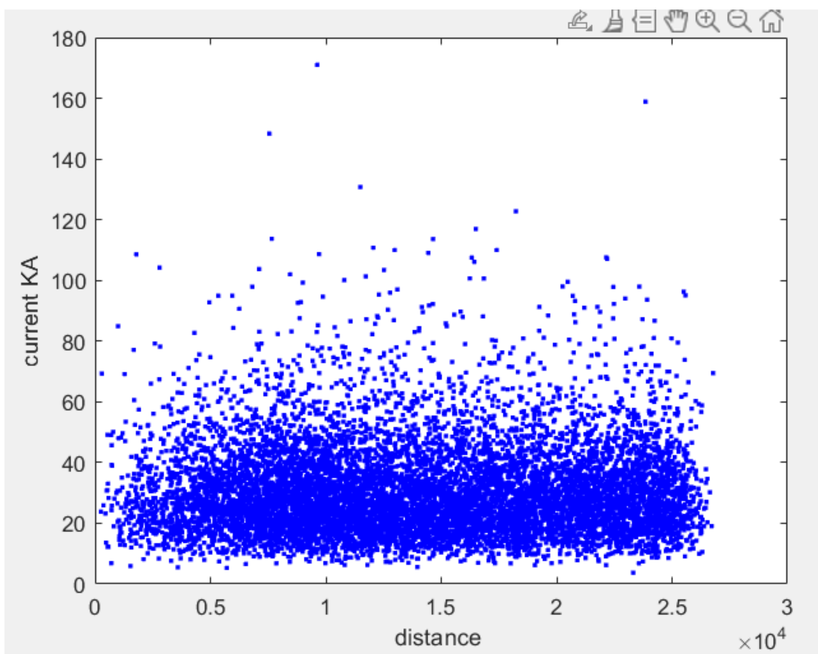

FIGURE 5, CURRENT OF EACH LIGHTNING, NOT RELATED WITH DISTANCE

The median value for lightning current is 27.63KA

Brief discussion about the obtained overvoltage values:

For the calculation of induced overvoltage's due to indirect lightning strikes we used the rusk method:

Where **v** is the speed of propagation return stroke (m/s) and **c** is the speed of light (c=3e8 m/s).

Return stroke speed for natural lightning varies between **0.29×10^8 m/s (29000 km/s) and 2.4×10^8 m/s … or:**

$$v_{RS} = \frac{c}{\sqrt{1+\frac{500}{I_p}}}$$

The **Rusk** model serves to predict the maximum overvoltage **U_m (kV)** for a peak stroke **current I_p (kA)** at a distance **d (m)** from a line of height **h (m)**:

$$U_m = 30\left(1+\frac{v/c}{\sqrt{2-(v/c)^2}}\right)\left(\frac{h\,I_p}{d}\right)$$

For strikes closer than 200m, we are reaching close to 12KV of induced overvoltage in the line

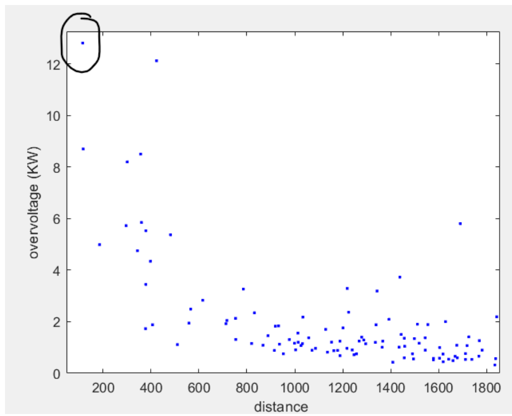

FIGURE 6, OVERRVOLTAGE DETAIL CLOSEST DISTANCES

After 5km the induced overvoltages are not that dependant of distance, the distribution flattens around the median value of 0.11Kv and a standard deviation of 0,77

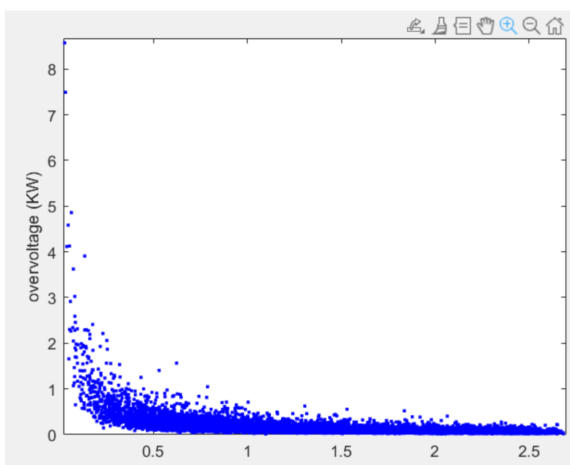

FIGURE 7, SAME AS FIGURE 3, OVERVOLTAGE DEPENDING OF DISTANCE

Result and discussion of the obtained risk:

In order to calculate the risk of isolation failure we need first to calculate the stress and strength of isolation curves

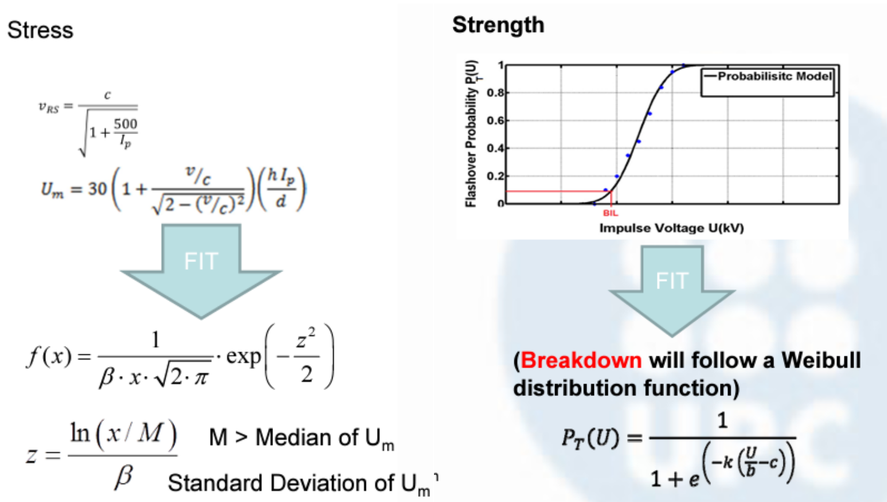

FIGURE 8, BOTH FORMULAS USED TO CALCULATE OUR STRESS AND STRENGTH DISTRIBUTIONS

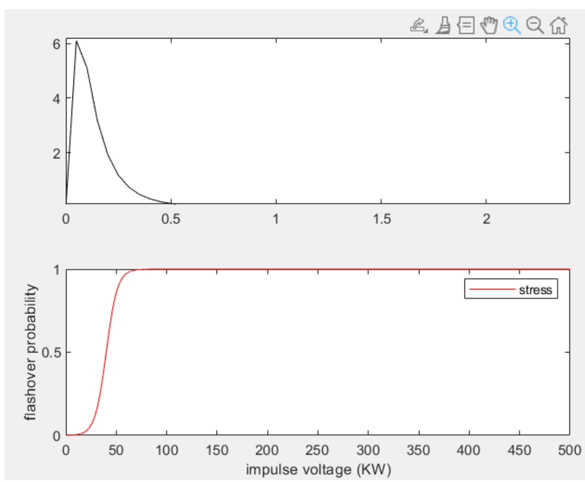

FIGURE 9, BOTH STRESS AND STRENGTH CURVES FOLLOW THEIR RESPECTIVE EXPECTED DISTRIBUTION SHAPES

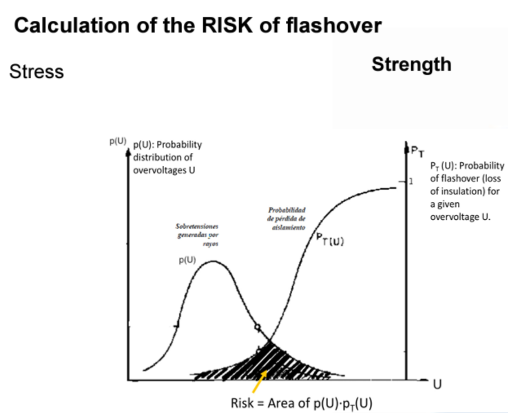

FIGURE 10, SNAP FROM THE COURSE SLIDES, HOW TO CALCULATE THE RISK

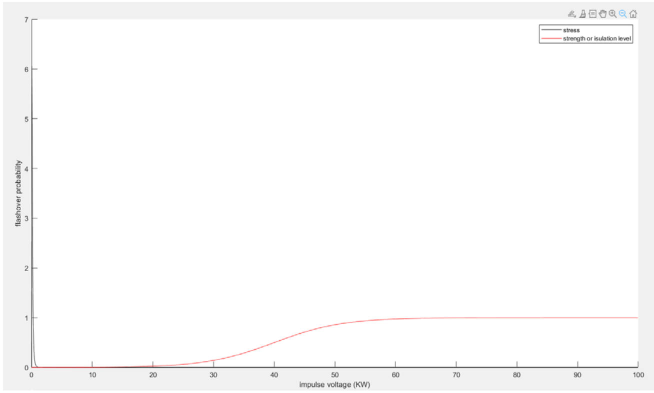

Figure 11, our stress and strength curves together

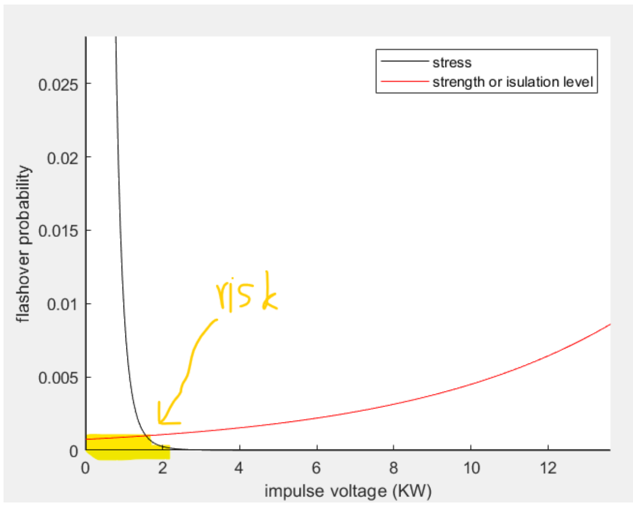

Figure 12, detail of stress and strength curves overlapping

Resulting risk of flashover after adding up the area under both curves = 0.0761%

Annex, matlab code:

```
clear;
clc;
close all;

N = 10000;

for i = 1:N
    data(i,1) = rand*20000;
    data(i,2) = rand*50000;
end


plot(data(:,1),data(:,2),'b. ');
xlabel('Lon (m)')
ylabel('Lat (m)')

%calc stats
mediaX = mean(data(:,1));
medianaX = median(data(:,1));
mediaY = mean(data(:,2));
medianaY = median(data(:,2));

%calc ground flash density

%lightning current dis
mu=log(27.7); %peak current value > for any LLC
sigma=0.461; % standadr deviation

c = 3e8; %sp of light

%calc overvoltages due to near strike

h = 1+0.5; %(m)

%power line location in horizontal plane
x_loc = 10000;%now we do an specific point
y_loc = 25000;



for i = 1:1:N
    data(i,1) = rand*20000; % x
    data(i,2) = rand*50000; % y
    data(i,3) = lognrnd(mu,sigma); %random log normal distribution of the lightning peak current
    data(i,4) = c/(sqrt(1+(500/data(i,3)))); %return stroke speed.

    test(i,1) = log(data(i,3)); % log (I) to calculate

    %check if not a direct strike


    d(i,1) = sqrt((x_loc-data(i,1))^2 +(y_loc-data(i,2))^2);%distance of the overvoltage, now from a
single point

    data(i,5) = 30*(1+(data(i,4)/c)/sqrt(2-(data(i,4)/c)^2))*(h*data(i,3)/d(i,1)); %overvoltage value for
each strike
    test(i,2) = log(data(i,5));
end


% current statistics
median_I=median(data(:,3));
std_I=std(test(:,1));

%overvoltage stats
```

```
median_U=median(data(:,5));
std_U=std(test(:,2));

i=1;
for U=0.0001:0.05:500 %distribution value of the stress curve, we choose 500KW but we could choose more than that, it will chop the infinit""" distribution
    P_U(i,1)=U;
    z=log(U/median_U)/std_U;
    P_U(i,2)= (1/(std_U*U*sqrt(2*pi)))*exp(-1*(z^2)/2);
    i=i+1;
end

%cumulative distribution function, not used a lot
[fil,col]=size(P_U);%get size of P_U, use the size as index
acc(1,1)=0;
j=2;
for i=2:1:fil
    acc(j,1)=acc(j-1,1)+P_U(i,2)*(P_U(i,1)-P_U(i-1,1));
    j=j+1;
end

%k=1.8 b=10 c=4 parameter of weibull distribution (shape and scale)

i=1;
for U=0.0001:0.05:500 %i believe this is the isulation curve somehow
    Pt_U(i,1)=U;
    Pt_U(i,2)= (1/(1+exp(-1.8*((U/10)-4))));
    i=i+1;
end

%calculation of risk, convolution
[fil,col]=size(P_U);
risk=0;
deltaU= (P_U(2,1)-P_U(1,1));
for i=1:fil
    risk=risk + (P_U(i,2)*Pt_U(i,2))*deltaU;
end

risk




figure();
hold on
plot(P_U(:,1),P_U(:,2),'k'); % doesnt make a lot of sense because also depends of DISTANCE so , if there is a grat induced overvoltage it could be that its just too close to the power line
hold on
plot(Pt_U(:,1),Pt_U(:,2),'r'); %insulation curve? he calls it strength
xlabel('impulse voltage (KW)')
ylabel('flashover probability')
legend('stress','strength or isulation level');
hold off

figure();
plot(d(:,1),data(:,3),'b. ');
xlabel('distance ')
ylabel('current KA')

figure();
plot(d(:,1),data(:,5),'b. '); % doesnt make a lot of sense because also depends of DISTANCE so , if there is a grat induced overvoltage it could be that its just too close to the power line
xlabel('distance ')
ylabel('overvoltage (KW)')

figure();
histogram(data(:,5));
```

```
title('overvoltage');
xlabel('overvoltage (KW)')
ylabel('number of events')

figure();
plot(data(:,3),data(:,5),'b. ');
title('Current vs overvoltage');
xlabel('current of lighning (KA)')
ylabel('overvoltage KV')
```