X SICEL 2021

Transición energética en la 4ta revolución industrial

Universidad Tecnológica de Pereira

UNIVERSIDAD NACIONAL DE COLOMBIA

Comparison between Electrogeometric Model and Leader Progression Model for Transmission Lines Shielding Failure Rate

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I. Introduction

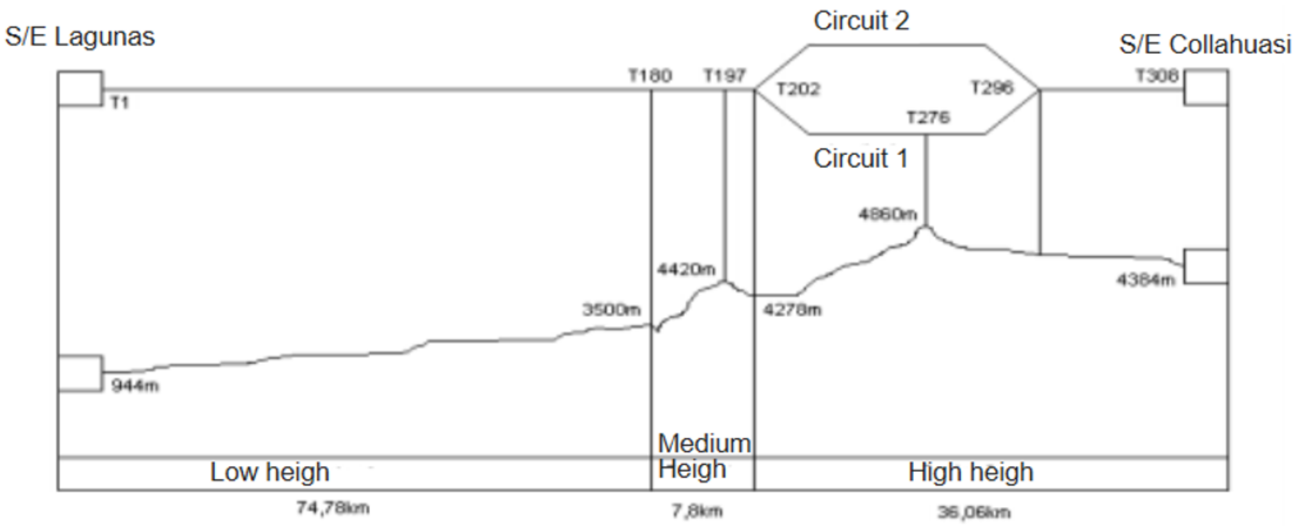
Why is an adequate shielding of transmission lines important?

- Allows a continuous supply of electrical energy
- Maintains the operational continuity of industry
- Protects the electrical equipment

I. Introduction

Case of study

- Transmission line Lagunas-Collahuasi



II. Theorical aspects

Electrogeometric Model

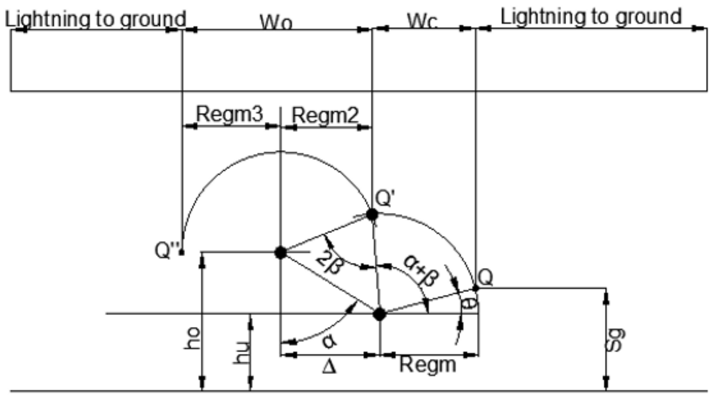
- Radius of the exposed and shielding arcs:

$$S(I_1) = A \cdot I_1^B$$

- Shielding Failure computation:

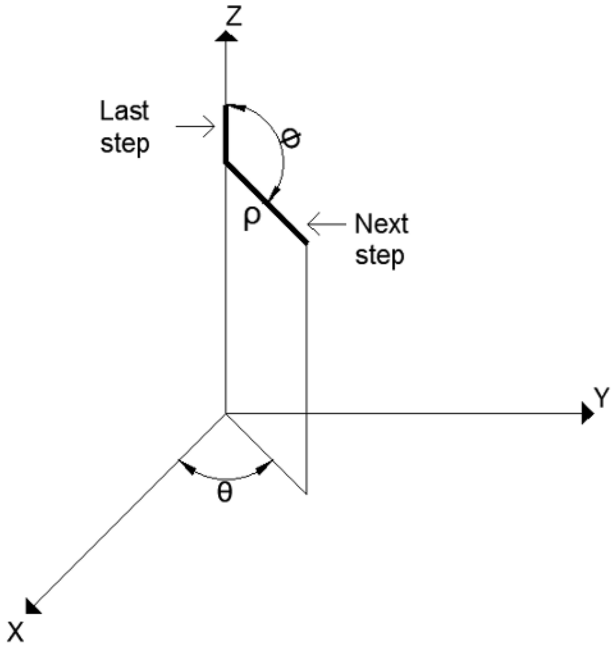
$$SFR_1 = \frac{2}{1000} \cdot GFD \cdot L \cdot \int_{I_{min}}^{I_{max}} W_u \cdot f_1(I) \cdot dI$$

$$SFFOR_1 = \frac{2}{1000} \cdot GFD \cdot L \cdot \int_{I_{crit}}^{I_{Max}} W_u \cdot f_1(I) \cdot dI$$



II. Theorical aspects

Leader Progression Model



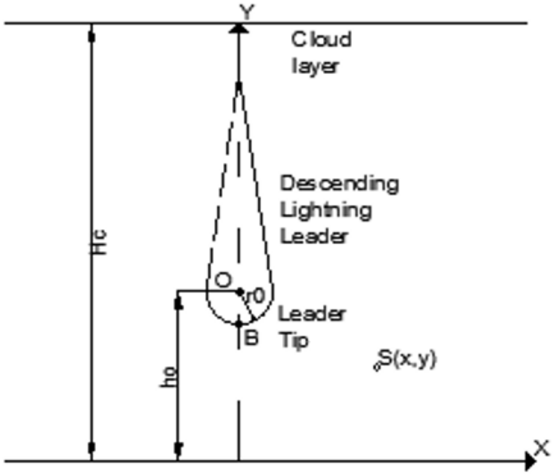
- $\emptyset$ *Gaussian distribution*
- θ *uniform distribution*
- ρ *uniform distribution*
- *Charge downward leader*

$$Q_T = \left(\frac{I}{25}\right)^{0.7} \quad Q_i = \frac{1}{\sum C_i} \cdot C_i \cdot Q_T$$

II. Theorical aspects

Leader Progression Model

- Downward leader Model



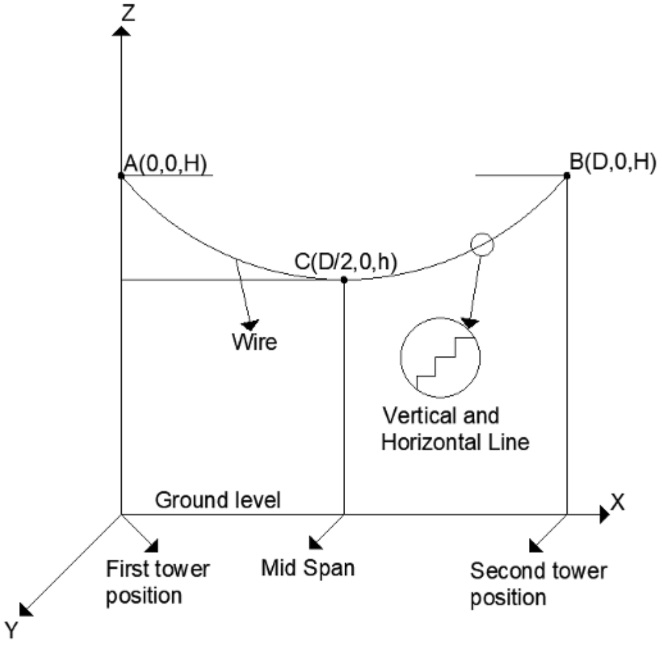
- Stable leader Inception criterion

$$U_c = \frac{2247}{1 + \frac{5.15 - 5.49 \cdot ln(a)}{d \cdot ln\left(\frac{2 \cdot d}{a}\right)}}$$

- Final Jump in reached when there is a potential gradient between the leaders greater than or equal to 500 [kV/m]

III. Proposed methodology

- Transmission line configuration



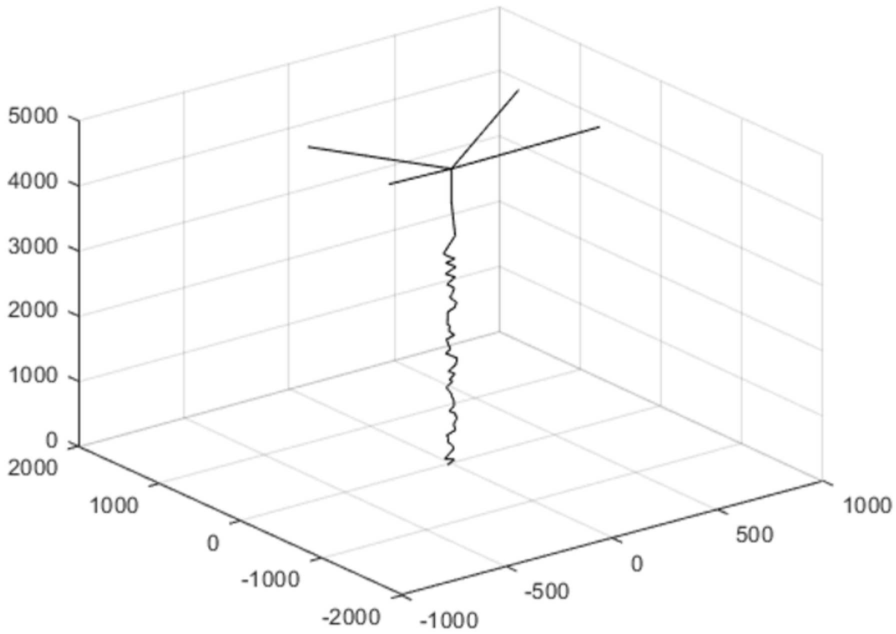
$$b = \frac{2}{D} \cdot ln \frac{H - \sqrt{H^2 - h^2}}{h}$$

$$z = h \cdot \cosh\left(b \cdot \left(\frac{D}{2} - x\right)\right)$$

- Matrix X contains horizontal coordinate
- Matrix Z contains vertical coordinate

III. Proposed methodology

Simulation MLP

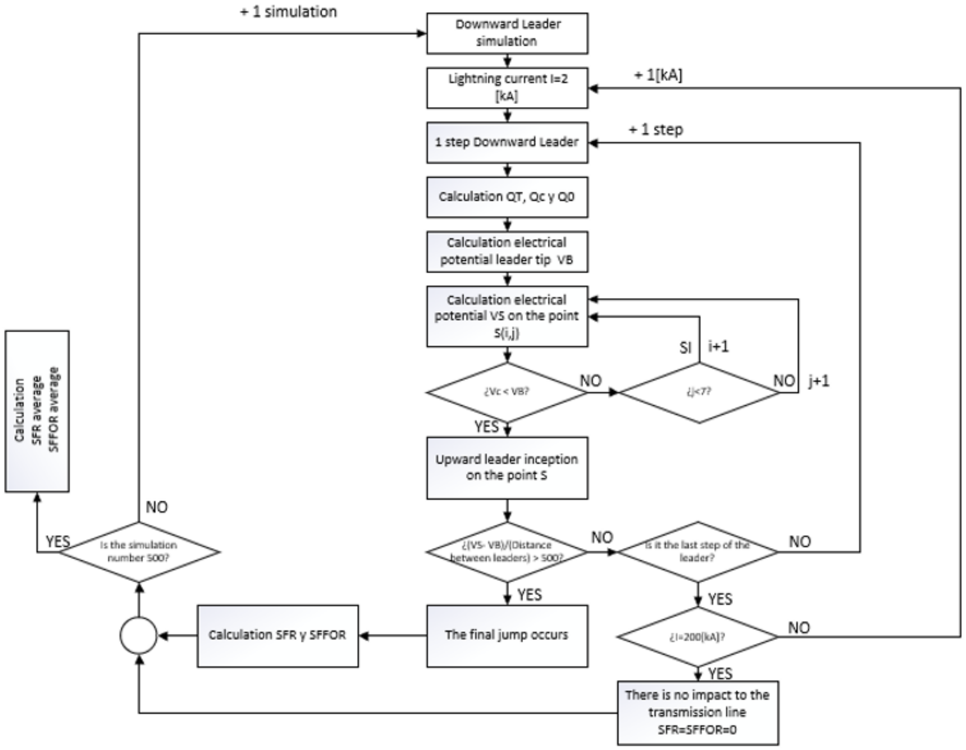


III. Proposed methodology

- Failure rates:

$$SFR = 0.1 \cdot T_d \cdot d \cdot \int_{I_{min}}^{I_{max}} P(I) \cdot dI$$

$$SFFOR = 0.1 \cdot T_d \cdot d \cdot \int_{I_{crit}}^{I_{max}} P(I) \cdot dI$$



IV. Results

Electrogeometric Model

Parameters	Low Height	Medium Height	High Height
Shield Angle	29	30.4	11.4
I_{crit} $[kA]$	4.96	5.9	4.91
I_{max} $[kA]$	12.25	19.25	7.03
$SFR \cdot 10^{-4}$	2.37	12	0.053
$SFR \cdot 10^{-4}$	1.93	11	0.04

IEEE recommends:

- Shielding angle < 30°
- Critical current < 5[kA]
- SFFOR < 0.05 [Lightning/year]

IV. Results

Leader Progression Model

Height	Low		Medium		High	
Impacts	I_{Min}	I_{Max}	I_{Min}	I_{Max}	I_{Min}	I_{Max}
1	43	200	57	200	81	200
2	22	200	31	200	136	200
3	72	200	68	200	108	200
4	188	200	20	200	171	200
5	41	200	140	200	177	200
6	135	200	16	200	165	200
7	69	200	15	200	123	200

Height	Low		Medium		High	
Impacts	I_{Min}	I_{Max}	I_{Min}	I_{Max}	I_{Min}	I_{Max}
8	133	200	133	200	93	200
9	138	200	31	200	180	200
10	153	200	137	200	147	200
11	–	200	38	200	33	200
12	–	200	68	200	40	200
13	–	200	164	200	164	200
14	–	200	108	200	7	200

IV. Results

Leader Progression Model

- Impacts of the phase conductor

Phases	Low Height	Medium Height
$X3$	3	6
$X2$	2	2
$X1$	0	0
$X3'$	0	0
$X2'$	1	2
$X1'$	4	4

Fases	High Height
$X1$	1
$X2$	5
$X3$	8

- Parameters

Height	$SFR_{Avarage}$	$SFFOR_{Avarage}$
Low	1.06607	1.06599
Medium	0.51295	0.51287
High	0.34562	0.34554

IV. Results

Comparison

Parameters	Low Heigh	Medium Heigh	High Heigh
SFR_{EGM}	$2.37 \cdot 10^{-4}$	$12 \cdot 10^{-4}$	$0.053 \cdot 10^{-4}$
SFR_{LPM}	1.06607	0.51295	0.34562
$SFFOR_{EGM}$	$1.93 \cdot 10^{-4}$	$11 \cdot 10^{-4}$	$0.04 \cdot 10^{-4}$
$SFFOR_{LPM}$	1.06599	0.51287	0.34554
$Time_{EGM}\ [seg]$	53	54	53
$Time_{LPM}\ [seg]$	28800	3120	61200

V. Conclusion

- The results from EGM obtained in the OTL indicated that the shielding should be adequate, but in the practice the SFR and SFFOR could underestimed.

- The comparison between models showed that the SFR and SFFOR values have big differences. The values obteneid by LPM are around 10^{-1} and the values of EGM are around 10^{-4}.

- The great difference between the previous parameters could show that the physical considerations taken by the LPM, manage to obtain a shielding state more similar to reality.

V. Conclusion

- The range current for which an impact can ocurrs for EGM is between 4 kA and 20 kA, while the range for LPM is between 7[kA] and 200 [kA].

- The computational time to calculate the SFR and SFFOR with LPM could be hours, in contrast the EGM could be minutes.

- The results of LPM could better represent the real OTL, but it is a model in development that needs to be contrasted with field tests.