

# **IT 002 – SOBRETENSÕES EM SISTEMAS DE ENERGIA ELÉTRICA**

## **Aula-10-Parte2**

### **Simulação de Descargas atmosféricas em Linhas de Transmissão no ATP**

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## Simulação no ATP:

- Linhas de Transmissão frente a descargas atmosféricas
- Linhas de Transmissão com Para-raios

# LT frente a descarga atmosférica

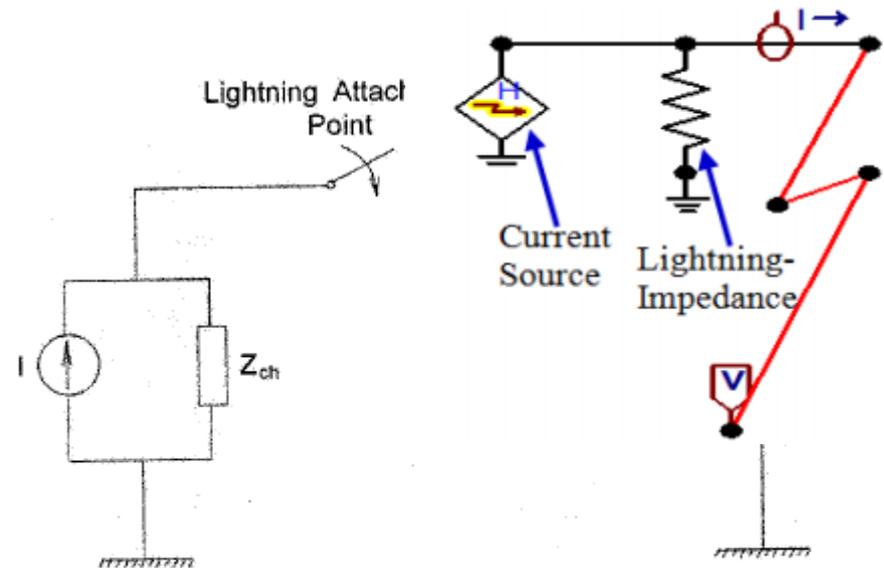
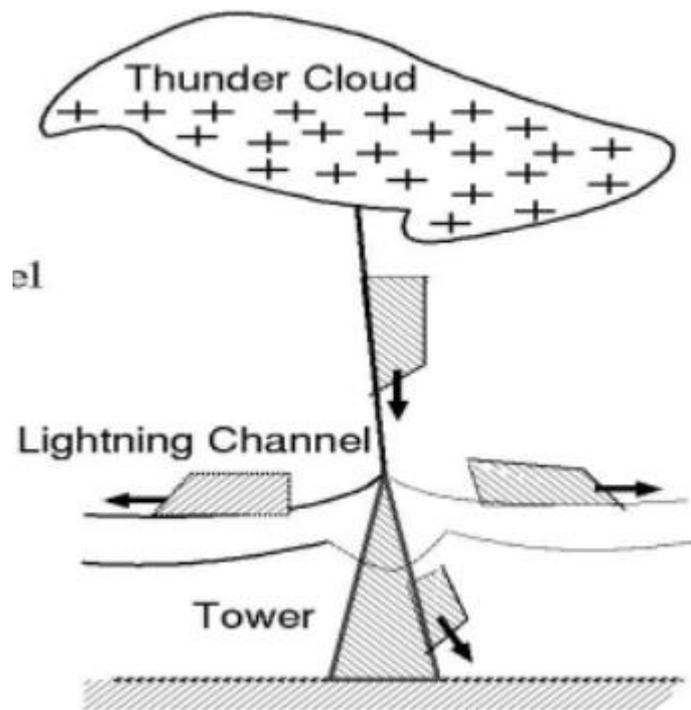
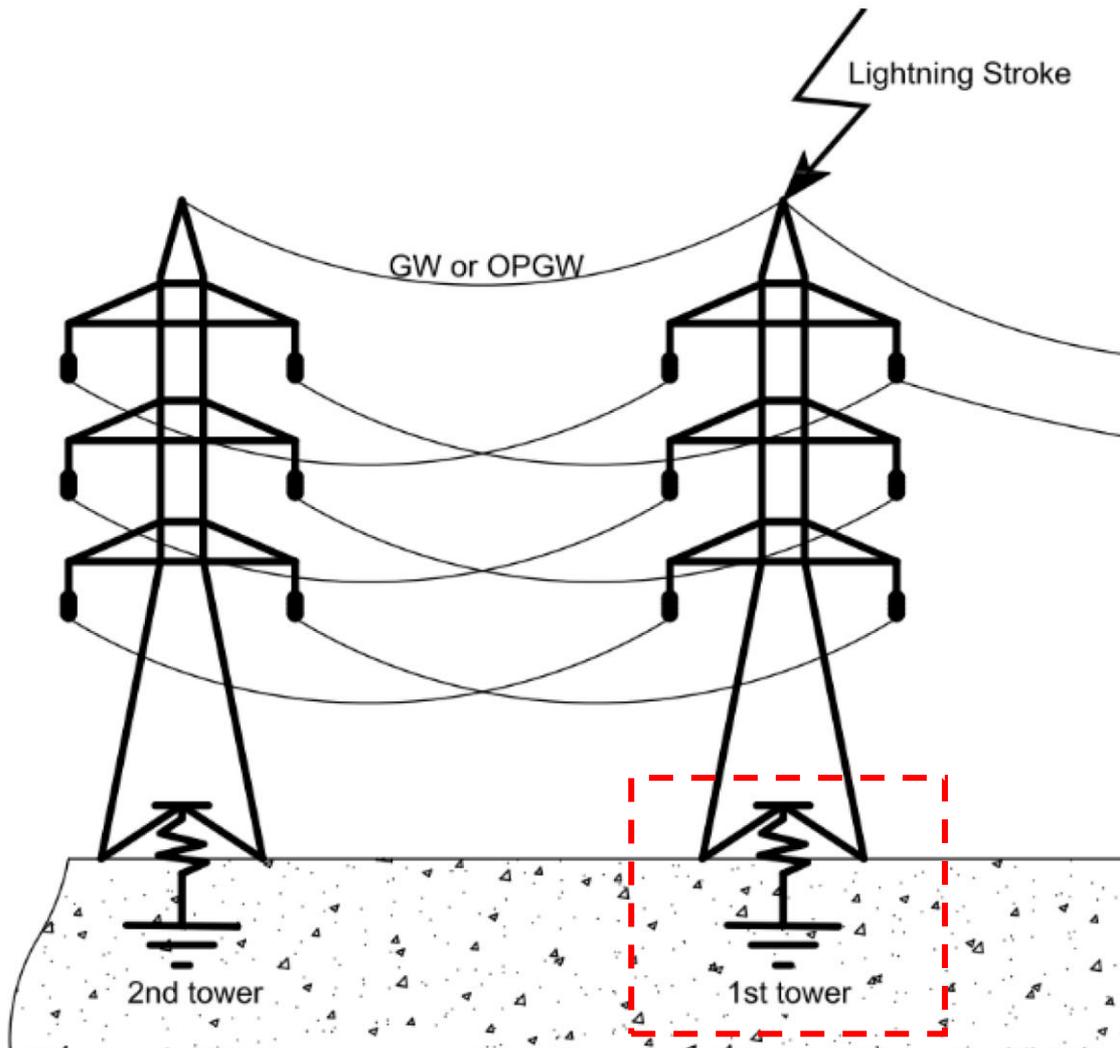


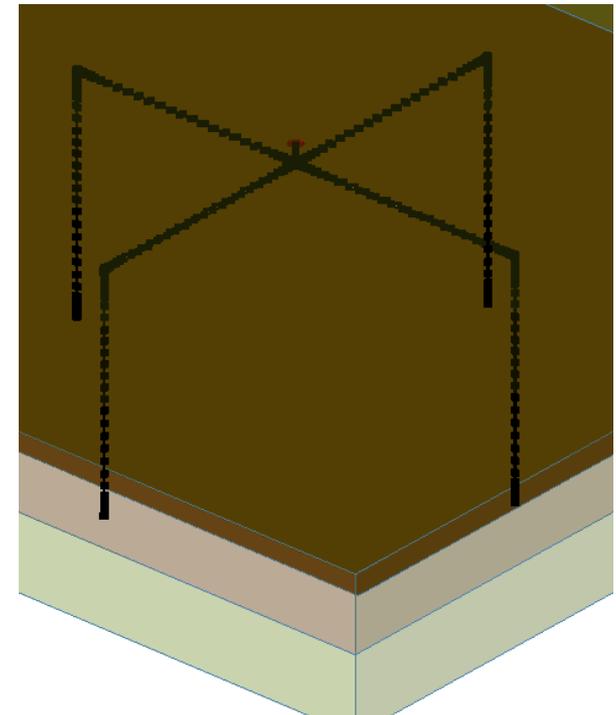
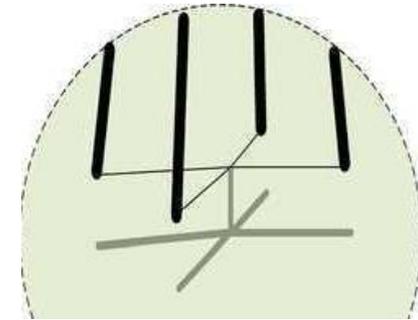
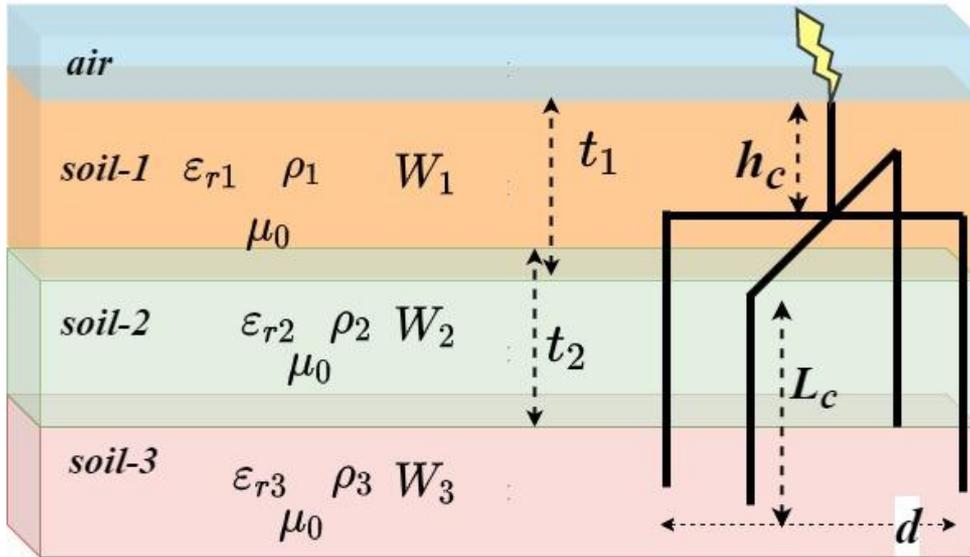
Fig. 3. Equivalent circuit for the case of lightning strike to ground or to an object of negligible height. Lightning is represented by a Norton equivalent circuit composed of an ideal current source representing the short-circuit current  $I$  in parallel with a lightning channel equivalent impedance  $Z_{ch}$ .  $Z_{gr}$  is the effective grounding impedance at the lightning attachment point, and  $I_{meas}$  is the current that would be measured at the attachment point.

# Sistema de Aterramento



- (1) Descarga Atmosférica
- (2) Sistema de Aterramento
- (3) Torre de Transmissão
- (4) Linhas de Transmissão

# Sistemas de Aterramento

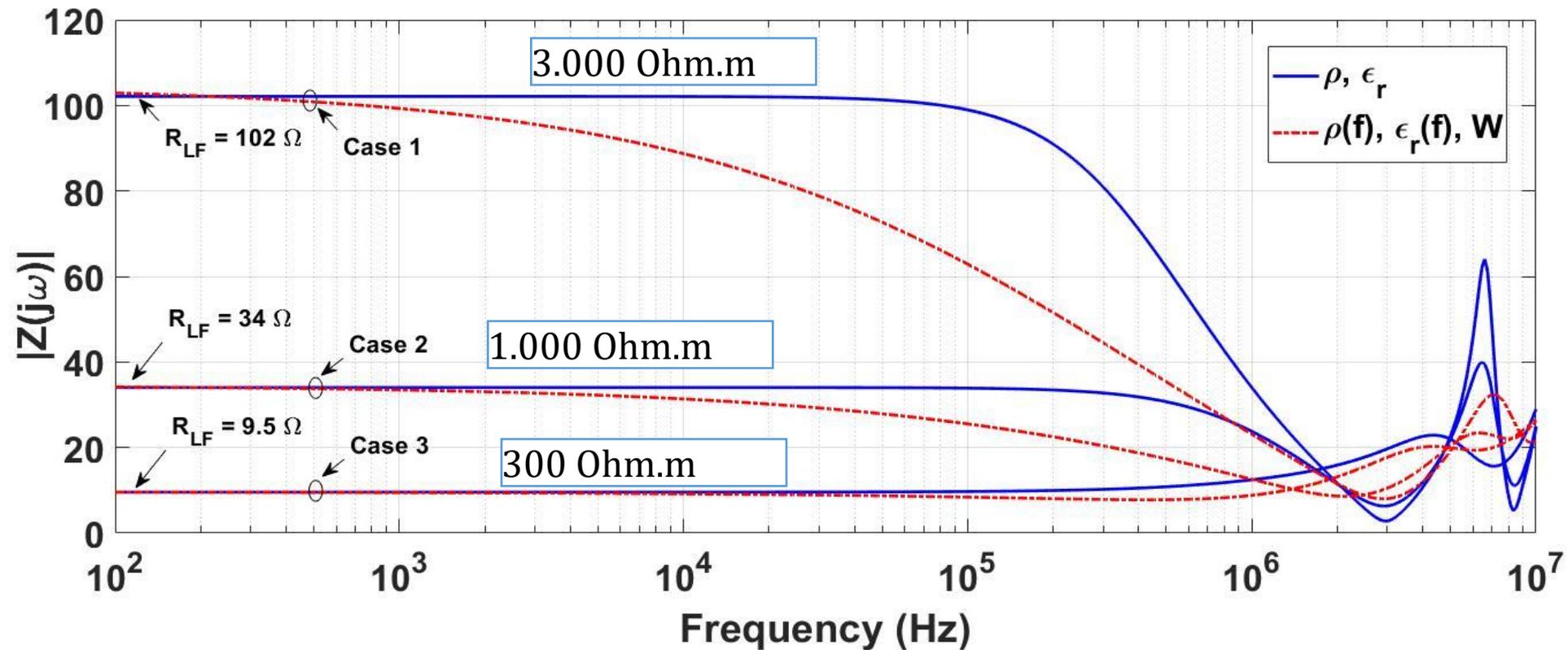


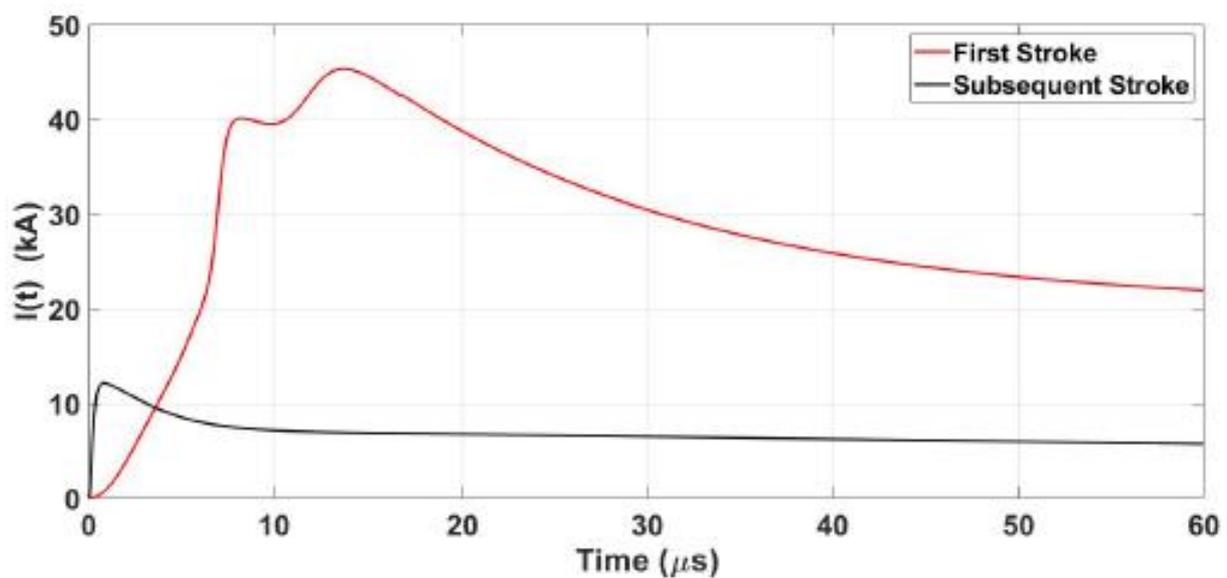
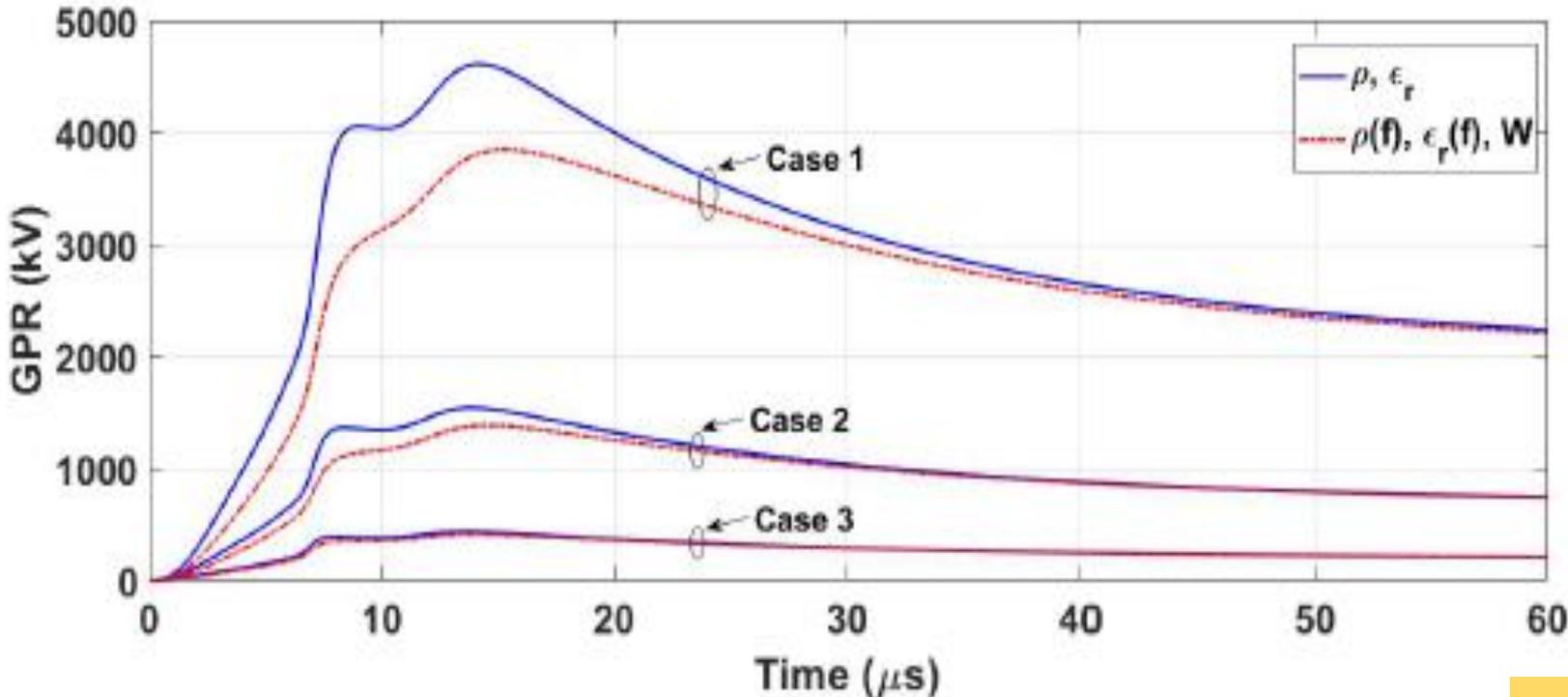
$$\epsilon_r(f) = \frac{\epsilon_\infty}{\epsilon_0} \left( 1 + \sqrt{\frac{1}{\pi f \epsilon_\infty \rho_{dc}}} \right)$$

$$\rho(f) = \frac{\rho_{dc}}{1 + \sqrt{4\pi f \epsilon_\infty \rho_{dc}}}$$

$$\rho_{dc} = \frac{1}{8 \times 10^{-3} \left(\frac{W}{10}\right)^{1.54}}$$

# Impedância harmônica

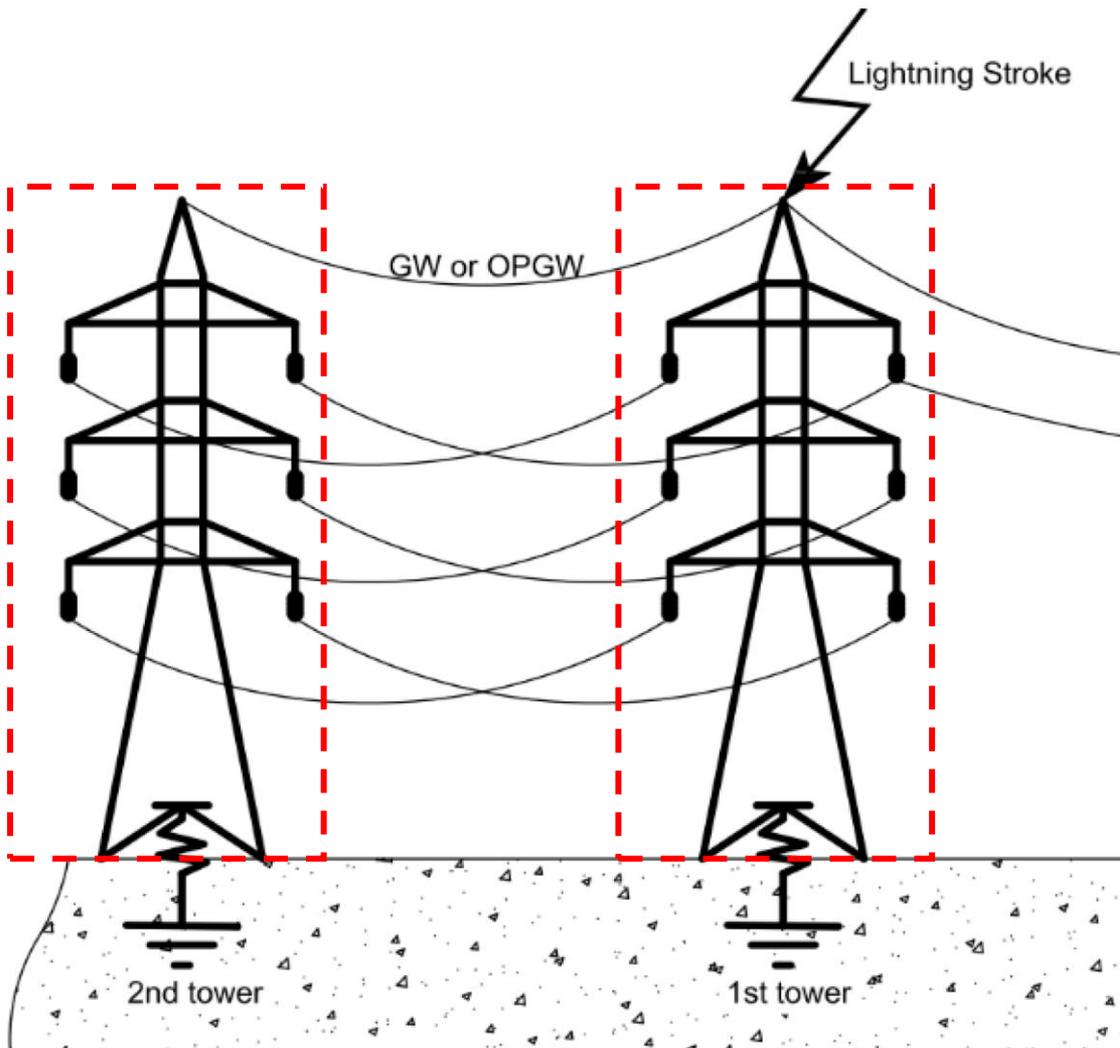




$$Z_P = \frac{V_P}{I_P}$$

case	First Stroke	
	FI soil $Z_P$	FD soil $Z_P$
1	101.86	85.00
2	34.03	30.54
3	9.59	9.06

# Torres de Transmissão



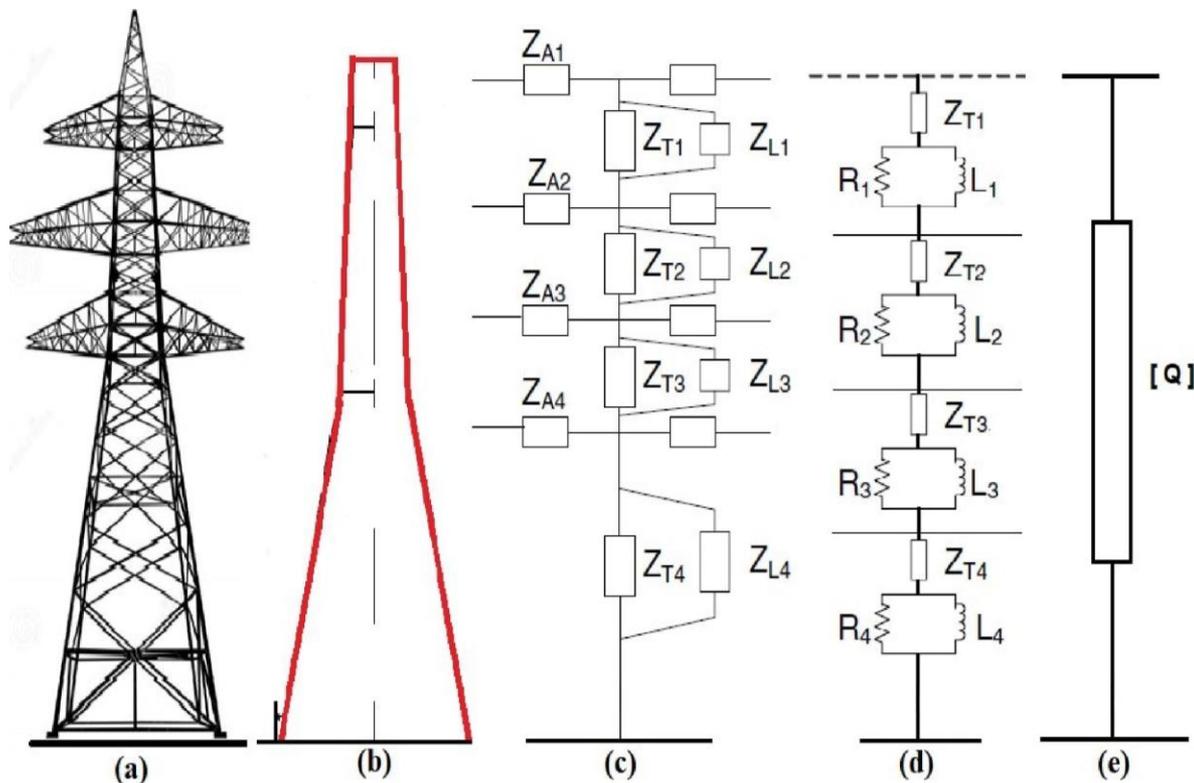
- (1) Descarga Atmosférica
- (2) Sistema de Aterramento
- (3) Torre de Transmissão
- (4) Linhas de Transmissão

# Modelagem de torres de transmissão

Diversos modelos foram desenvolvidos para representar uma TT convencional e calcular sua impedância de surto.

Esses são classificados em:

- (a) Modelos aproximados por geometria simples;
- (b) Modelos compostos por multicondutores;
- (c) Modelos de torre "multi-andares";
- (d) Modelos de torres dependentes da frequência-Quadripolos.



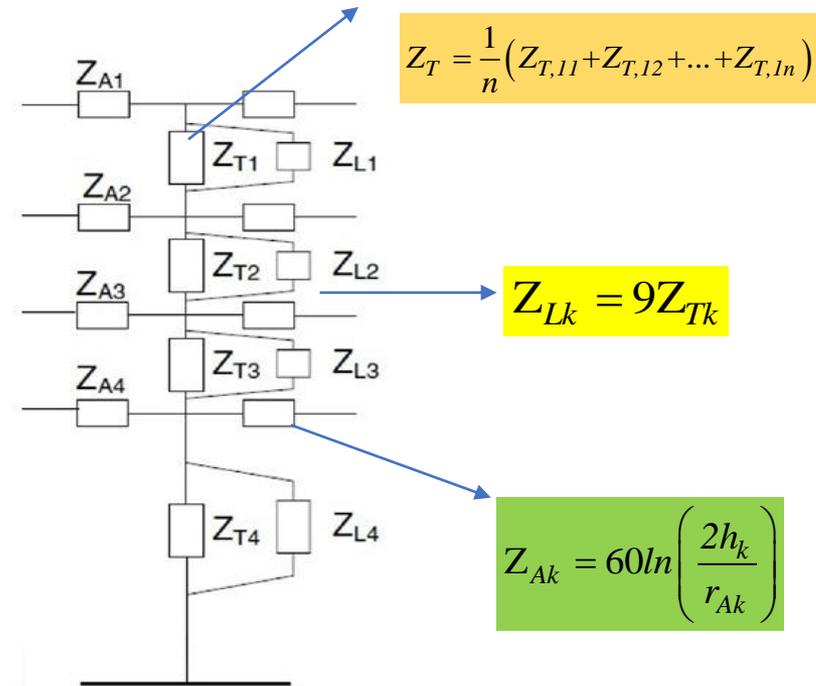
# Modelos multicondutores

- ❖ A torre é composta por linhas curtas sem perdas (ZT) que representam as pernas, as treliças (ZL) e os braços (ZA);
- ❖ A torre é dividida em 4 trechos, e cada impedância é determinada por uma fórmula empírica.
- ❖ A impedância de cada parte da torre é dada em função das dimensões e geometrias, obtidos;
- ❖ Silhueta de uma torre de alta tensão; Modelo multicondutor vertical incluindo barras diagonais e braços de torre.



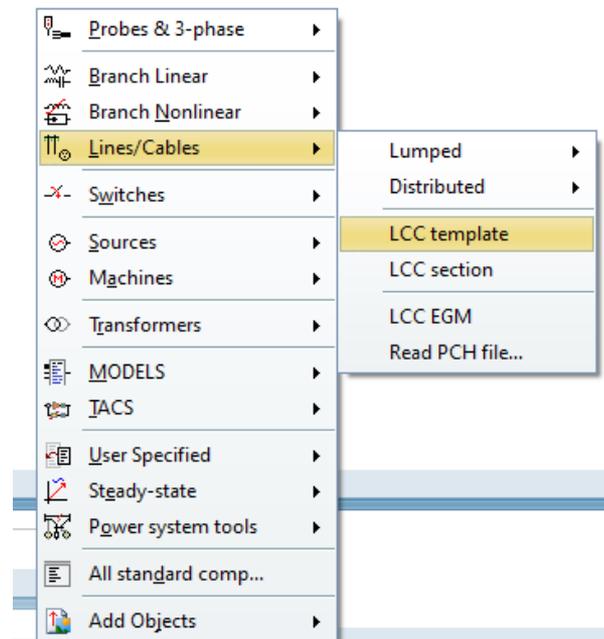
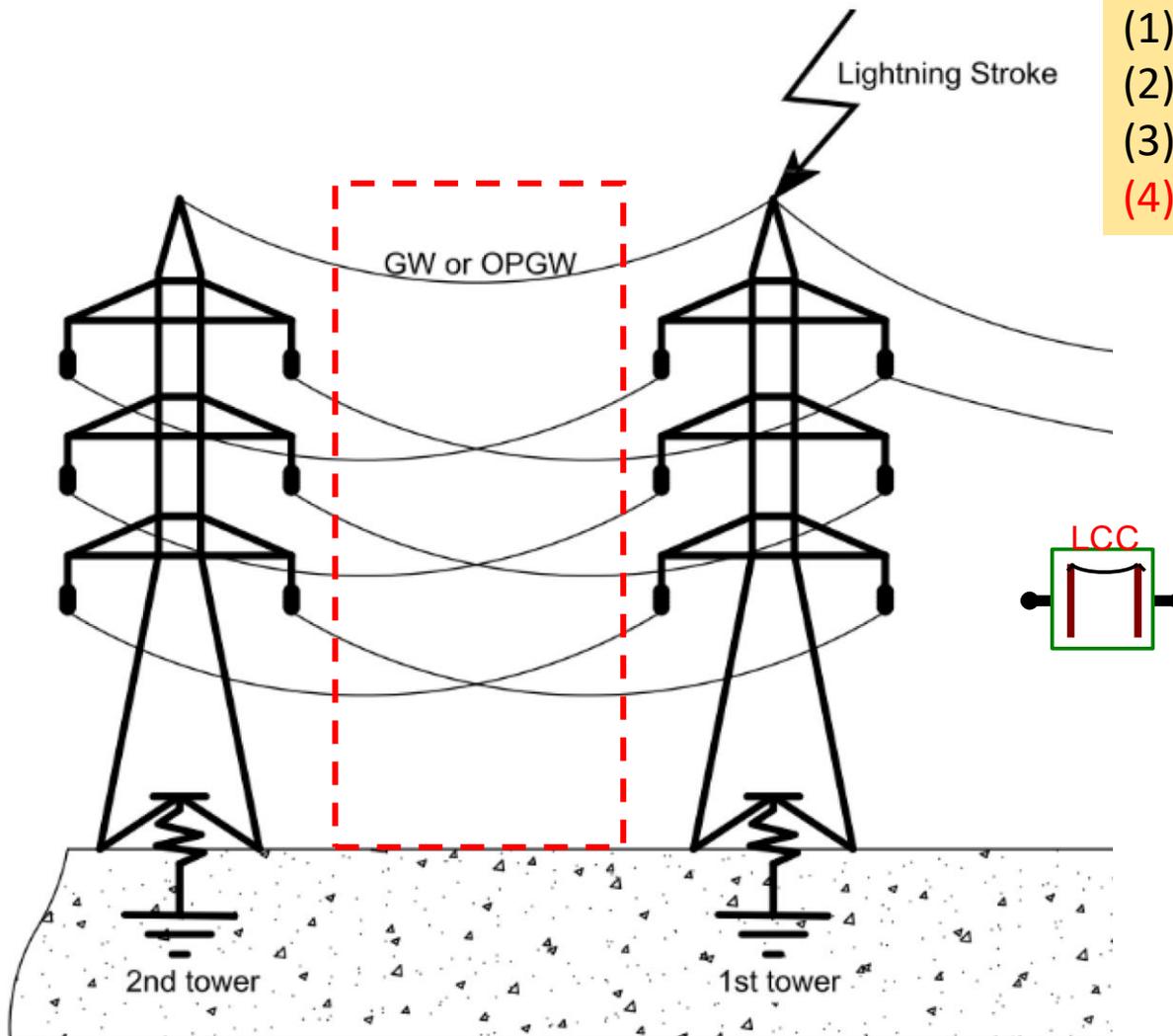
$$Z_{T,kk} = 60 \left[ \ln \left( \frac{2\sqrt{2}h}{r} \right) - 2 \right]$$

$$Z_{T,km} = 60 \left[ \ln \left( \frac{2\sqrt{2}h}{R_{km}} \right) - 2 \right]$$



# Linhas de Transmissão

- (1) Descarga Atmosférica
- (2) Sistema de Aterramento
- (3) Torre de Transmissão
- (4) Linhas de Transmissão



# Descargas Atmosféricas

MODEL: heidler\_7termos

Attributes	NODE	PHASE	NAME
	Itotal	1	XX0006

Comment:

Models Library

Model: heidler\_7termos

Model Editor

```
File Edit View Debug Done Help
1 MODEL heidler_7termos
2 OUTPUT Itotal
3 VAR Itotal, I0[1..7],n[1..7],t1[1..7],t2[1..7],Eta[1..7],I[1..7],k
4 INIT
5 I0[1..7]:=[6,5,5,8,16.5,17,12]*1E3
6 n[1..7]:=[2,3,5,9,30,2,14]
7 t1[1..7]:=[3,3.5,4.8,6,7,70,12]*1E-6
8 t2[1..7]:=[76,10,30,26,23.2,200,26]*1E-6
9 ENDINIT
10 EXEC
11 k:=1
12 WHILE k<=7 DO
13 Eta[k]:=exp(-(t1[k]/t2[k])*(n[k]*t2[k]/t1[k]))*(1/n[k])
14 I[k]:=(I0[k]/Eta[k])*((t1[k])**n[k])*exp(-t/t2[k])/(1+(t1[k])**n[k])
15 k:=k+1
16 ENDWHILE
17 Itotal:=I[1]+I[2]+I[3]+I[4]+I[5]+I[6]+I[7]
18 ENDEXEC
19 ENDMODEL
```

MODEL: heidler\_sub2

Attributes	DATA	UNIT	VALUE	NODE	PHASE	NAME
	Amp1		16734	Itotal	1	XX0021
	Amp2		7416.3			
	t11		2.5E-7			
	t21		2.5E-6			
	t12		2E-6			
	t22		0.00023			
	n		2			

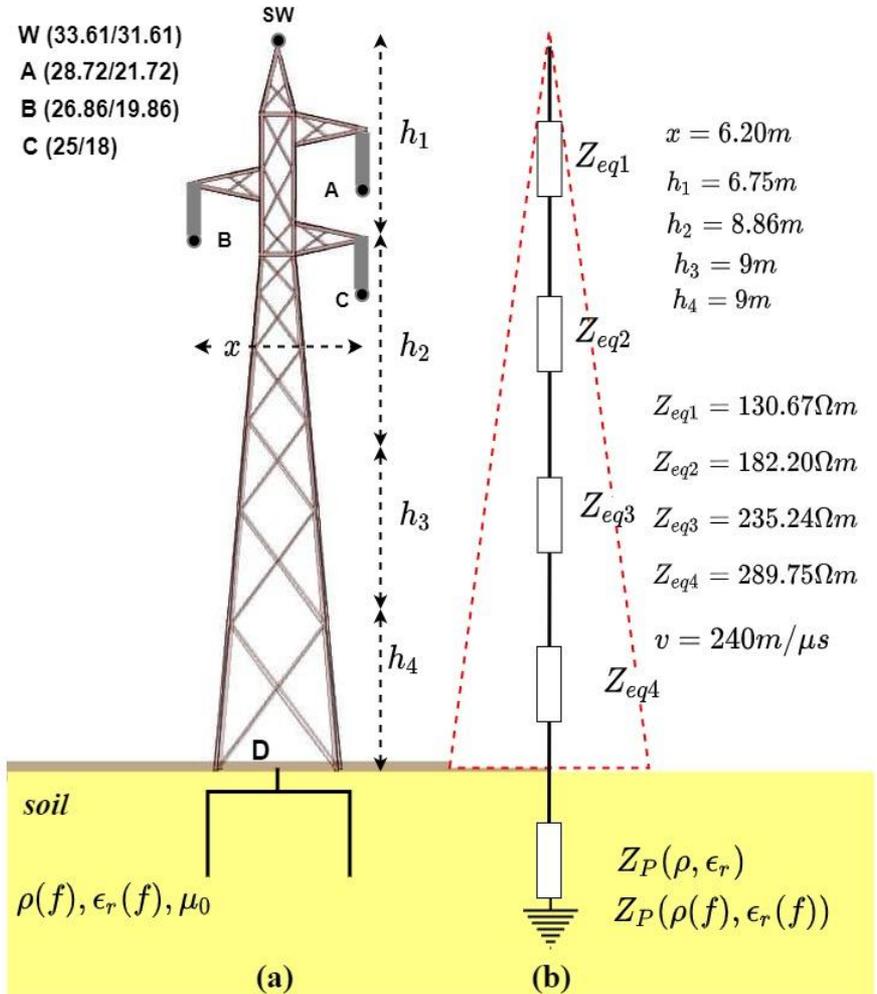
Copy Paste Reset Order: 0 Label:

Comment:

Models Library  Hide  Protect

Model: heidler\_sub2  Use As: DEFAULT

# Torre circuito simples



# Modelagem da linha de transmissão

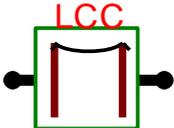
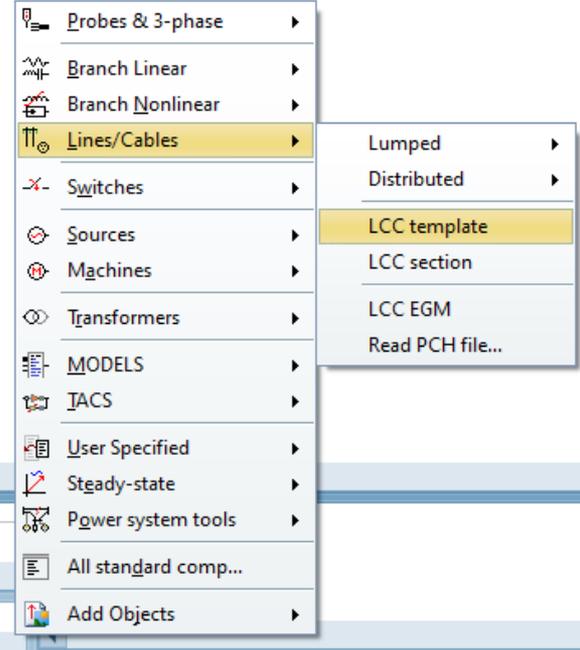
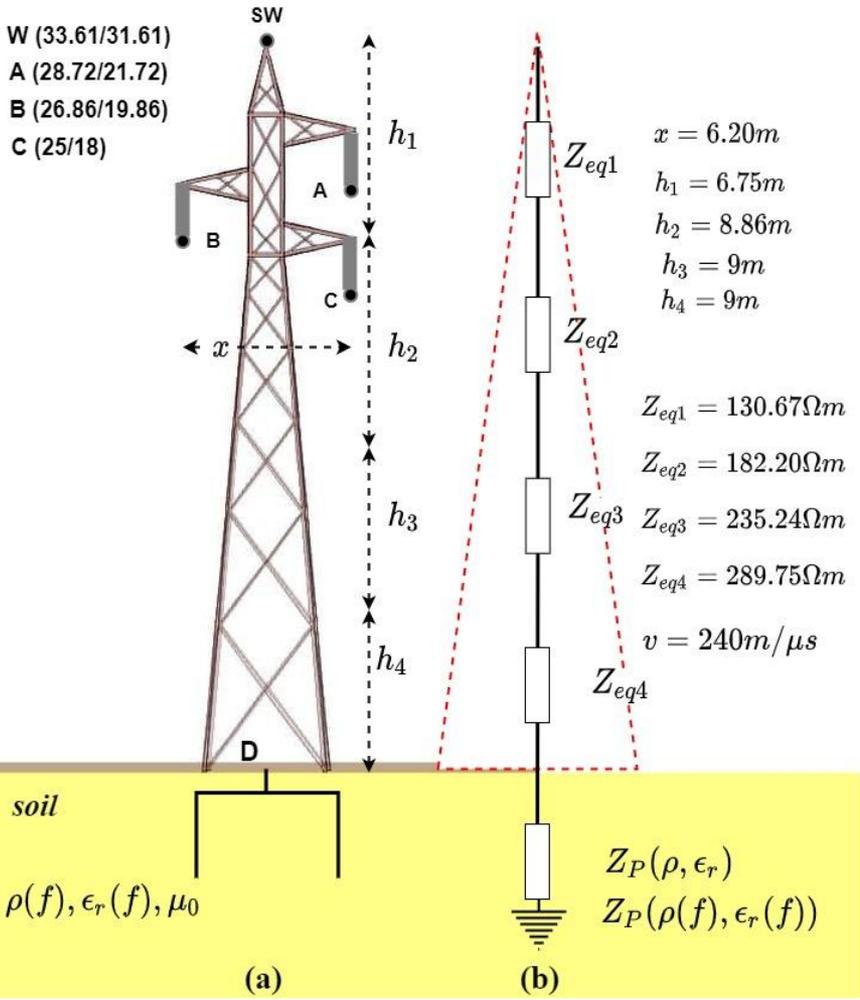
## ❖ Energização de uma Linha de transmissão trifásica

### Condutores de fase

- Longitude
- Tensão

### Condutores de fase

- Resistencia
- Raio\_in
- Raio\_ext
- Condutores de
- Resistencia
- Raio\_in
- Raio\_ext



# Simulação de manobras em linhas de transmissão.

Line/Cable Data: line\_tower

Model **Data** Nodes

System type  
 Name: line\_tower  
 Overhead Line  
 #Ph: 4  
 Transpose  
 Auto bundling  
 Skin effect  
 Segmented ground  
 Real transf. matrix

Standard data  
 Rho [ohm\*m] 1000  
 Freq. init [Hz] 0.1  
 Length [km] 0.42  
 Set length in icon

#	Ph.no.	Rin [cm]	Rout [cm]	Resis [ohm/km DC]	Horiz [m]	Vtower [m]	Vmid [m]
1	1	0.2976	0.9155	0.2032	3.2	28.72	21.72
2	2	0.2976	0.9155	0.2032	-3.2	26.86	19.86
3	3	0.2976	0.9155	0.2032	3.2	25	18
4	4	0	0.476	3.81	0	33.61	31.6

Units:  Metric  English

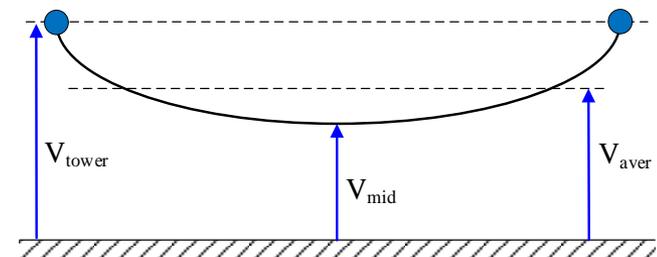
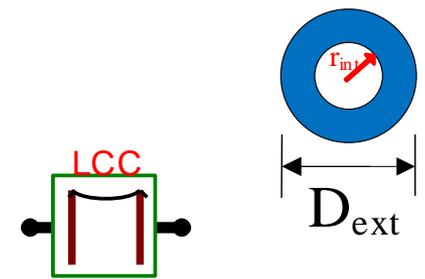
Model Type:  Bergeron  PI  JMarti  Noda  Semlyen

Data: Decades 8, Points/Dec 20, Freq. matrix [Hz] 1000, Freq. SS [Hz] 60,  Use default fitting

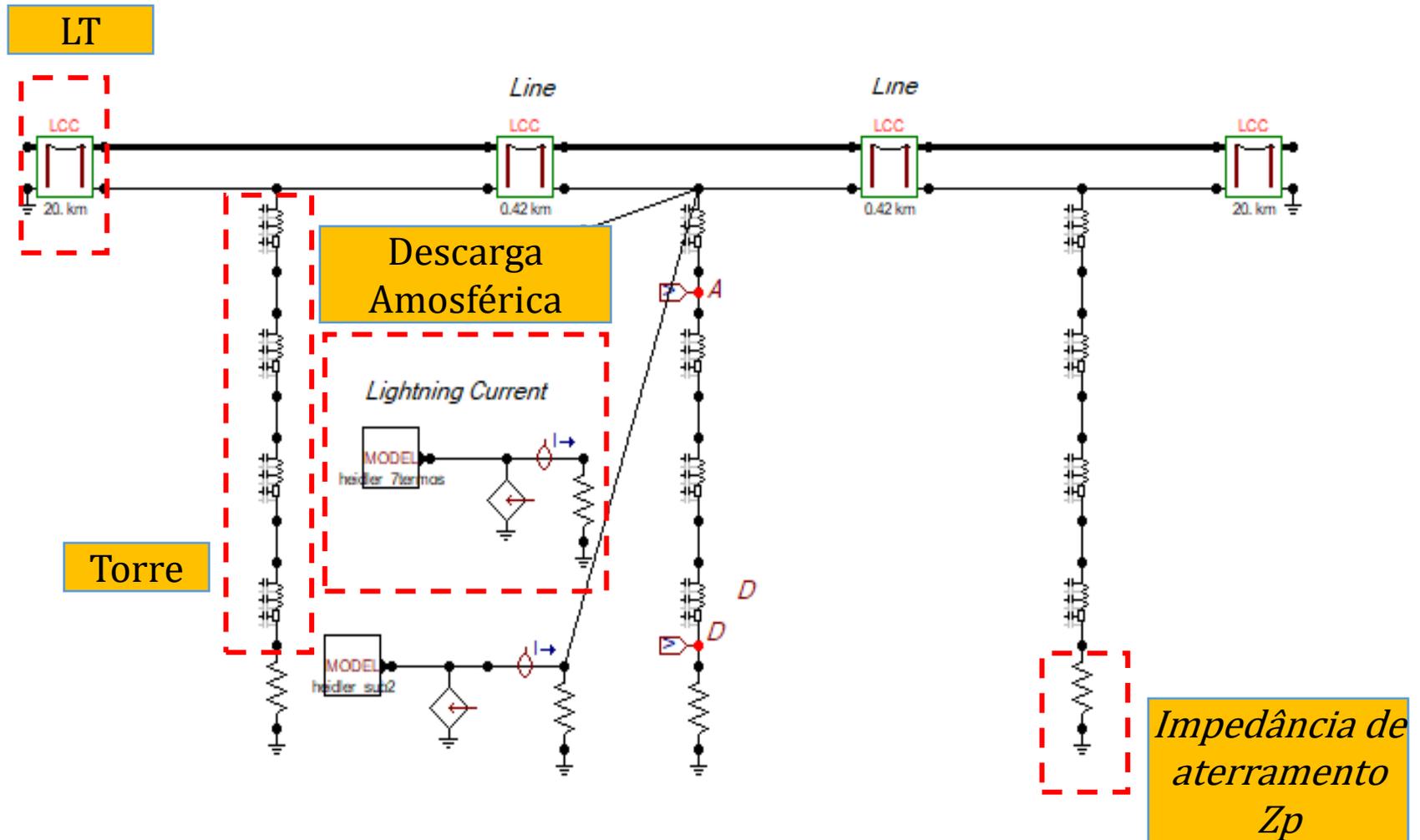
NAME	DEFAULT	VALUE
Idebug	1	1
lpunch	0	0
Koutpr	0	0
Gmode	3e-8	3E-8

Comment: Order: 0 Label: Hide

Buttons: OK, Cancel, Import, Export, Run ATP, View, Verify, Edit defin., Help

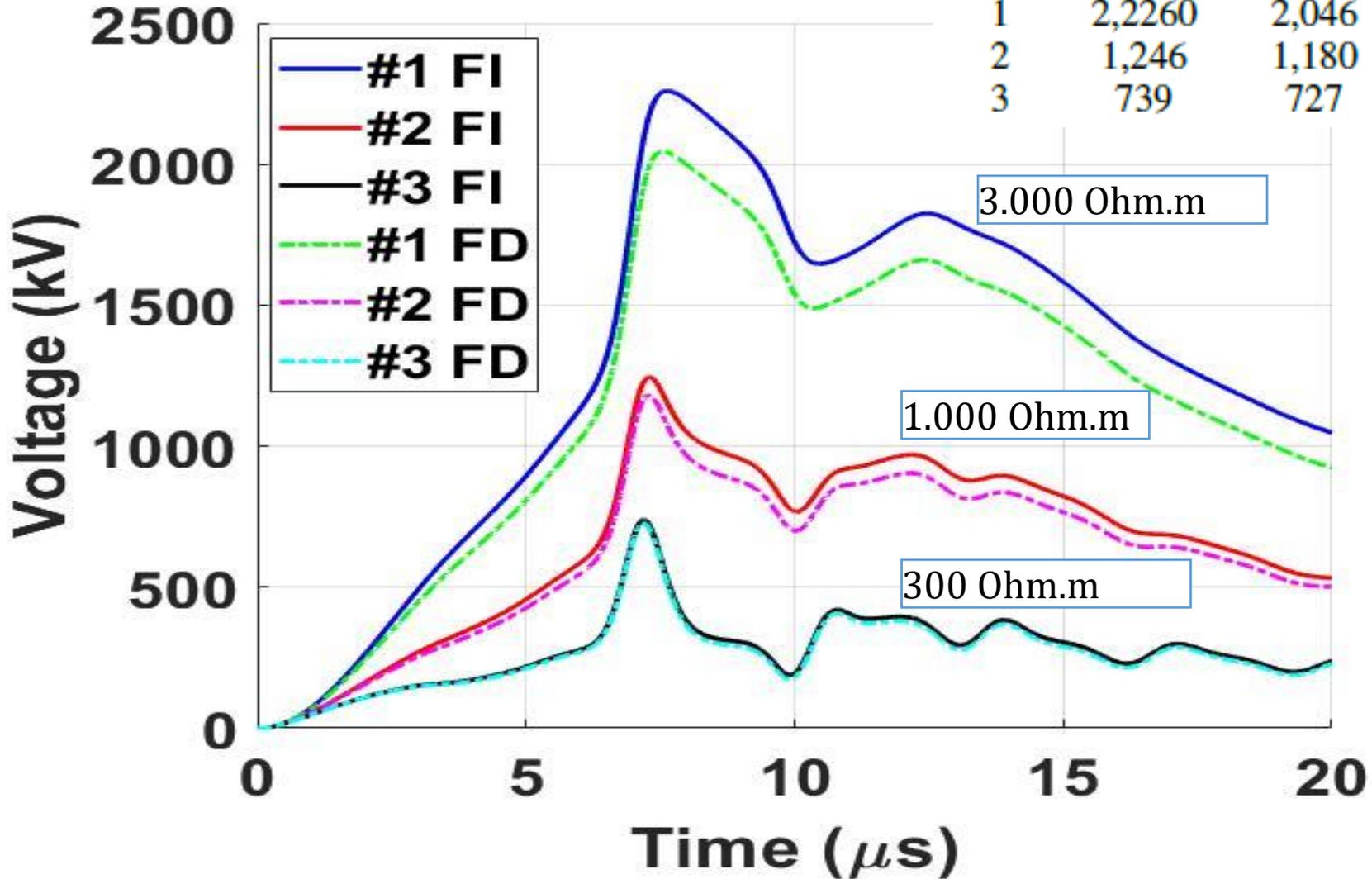


# Sobretensões por descargas

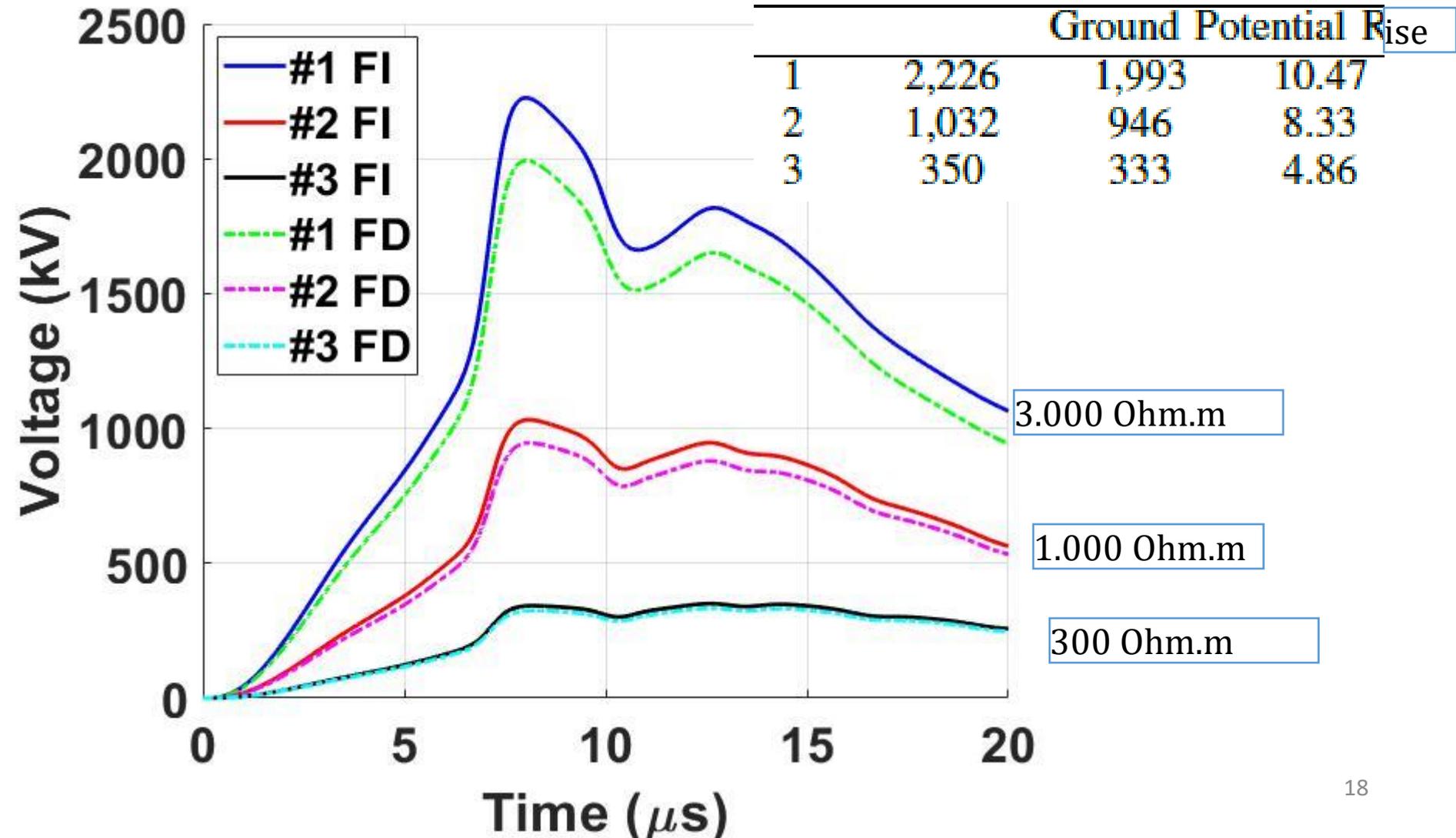


# Sobretensões na Fase A

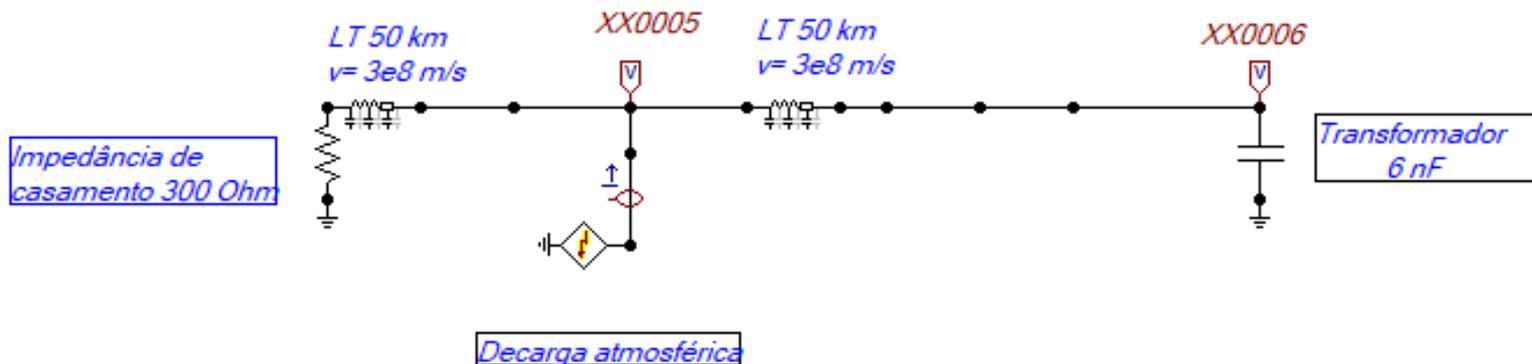
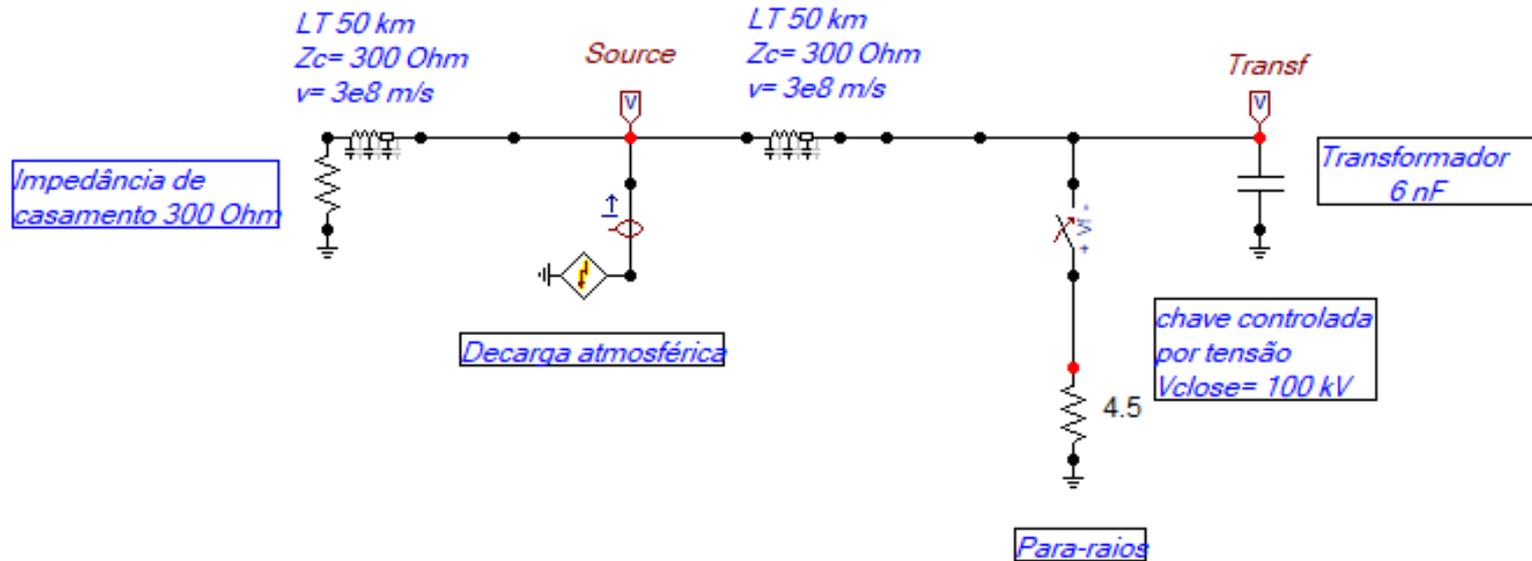
First Stroke			
Voltage across 1			
case	FI soil	FD soil	$\Delta(\%)$
1	2,2260	2,046	9.47
2	1,246	1,180	5.30
3	739	727	1.62



# Sobretensões (Ponto D)



# Linhas de Transmissão Com Pára-raios



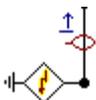
**Component: SURGE**

Attributes

DATA	UNIT	VALUE
Amplitude	Ampere	10000
A	1/s	-14700
B	1/s	-2470000
Tstart	s	0
Tstop	s	1000

Order: 0

Comment:



- Probes & 3-phase
- Branch Linear
- Branch Nonlinear
- Lines/Cables
- Switches**
- Sources
- Machines
- Transformers
- MODELS
- IACS
- User Specified
- Steady-state
- Power system tools
- All standard comp...
- Add Objects



- Switch time controlled
- Switch time 3-ph
- Switch voltage contr.**

**Component: SWITCHVC**

Attributes

DATA	UNIT	VALUE	NODE	PHASE	NAME
T-cl		0	SWF	1	SAon
T-de		7E-5	SWT	1	Transf
Imar		0			
V-fl		100000			

Order: 0

Label:

Comment:

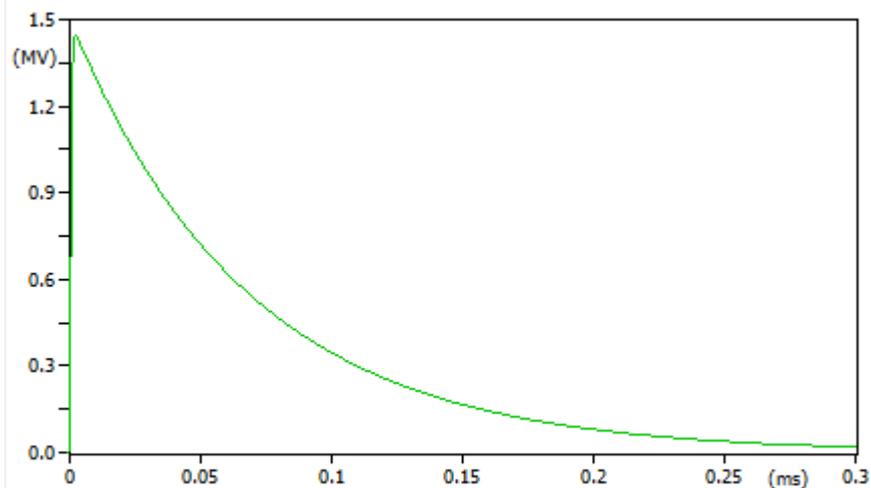
Output:   Hide

**Help Viewer**

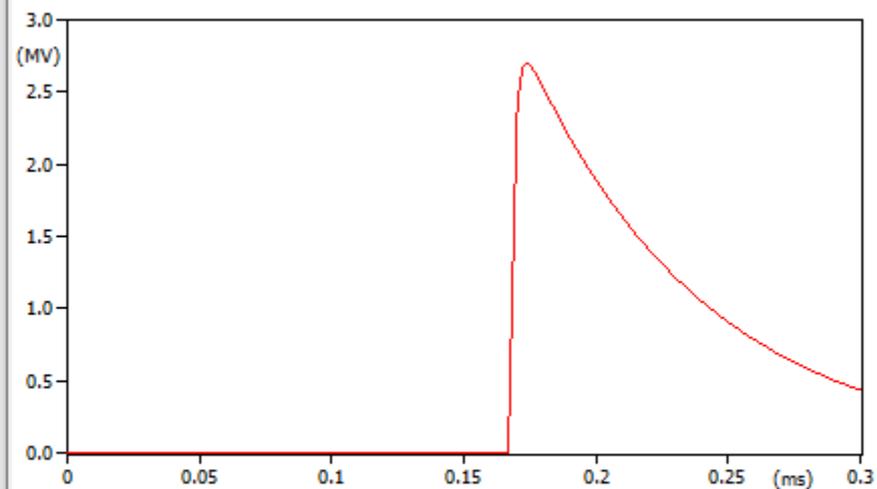
File Edit Character Help

Name : SWITCHVC - Voltage-controlled switch.  
 Card : SWITCH  
 Data : T-cl= Closing time of switch in [sec].  
 T-de= Minimum time in [sec] the switch must stay closed.  
 Imar= Current margin in [A].  
 Switch opens for Tclosed > T-de if |I|<Imar.  
 Advisable to use a non-zero Imar.  
 V-fl= Flashover voltage [V]. Switch closes for t>T-cl if |U|>V-fl.  
 Node : SWF= Start node of switch.  
 SWT= End node of switch.  
 RuleBook: VI.A.2.

MC's PlotXY - Plot 1



MC's PlotXY - Plot 2



MC's PlotXY - Plot 1

