VI Russian Conference on Lightning Protection

17th – 19th April, 2018
Saint Petersburg

Protective Effect of Shield Wires against Lightning-Induced Overvoltages on Distribution Lines

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OUTLINE

- Introduction
- Model (ERM)
- Shielding Factors
- Analysis (LIV, SW effectiveness)
- Conclusions

INTRODUCTION

MV lines – protective measures against short interruptions and voltage sags caused by lightning:

- **Increasing CFO**
- **Shield wire**
- **Surge arresters**

X

- **Direct strokes**
- **Indirect strokes**

→ **dependence of the SW effectiveness on some of the most important lightning, soil, and network parameters**

THE EXTENDED RUSCK MODEL (ERM)

$$\begin{cases} \dfrac{\partial V^s(x,t)}{\partial x} + \displaystyle\int_0^t \xi_g'(t-\tau)\,\frac{\partial}{\partial \tau} I(x,\tau)\,d\tau + L\,\frac{\partial I(x,t)}{\partial t} = -\frac{\partial \Phi^i(x,h,t)}{\partial x} - \frac{\partial A_x^{\,i}(x,h,t)}{\partial t} \\ \dfrac{\partial I(x,t)}{\partial x} + C\,\dfrac{\partial V^s(x,t)}{\partial t} = 0 \end{cases}$$

Inducing electric field (horiz. component)

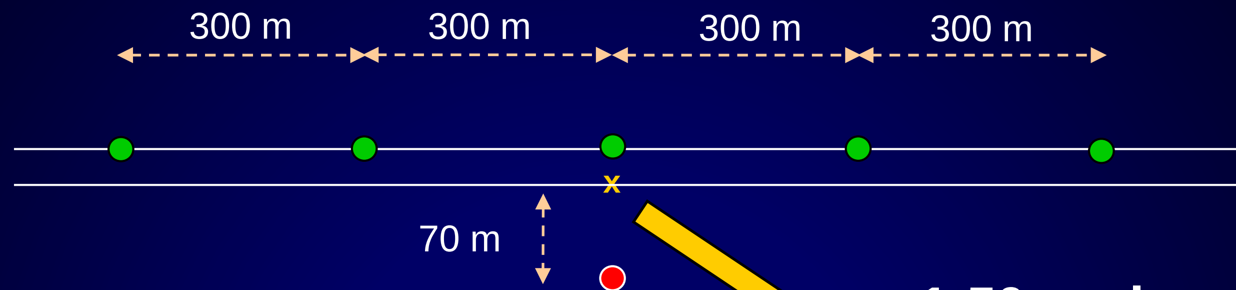
$$U(x,t) = V^s(x,t) + \int_0^h \frac{\partial \overline{A}_z^{\,i}(x,z,t)}{\partial t}\,d\overline{z}$$

$$\begin{cases} V^s(x_{máx},t) = Z_2.I(x_{máx},t) - h\,\dfrac{\partial A_z^{\,i}(x_{máx},t)}{\partial t} \\ V^s(0,t) = -Z_1.I(0,t) - h\,\dfrac{\partial A_z^{\,i}(0,t)}{\partial t} \end{cases}$$

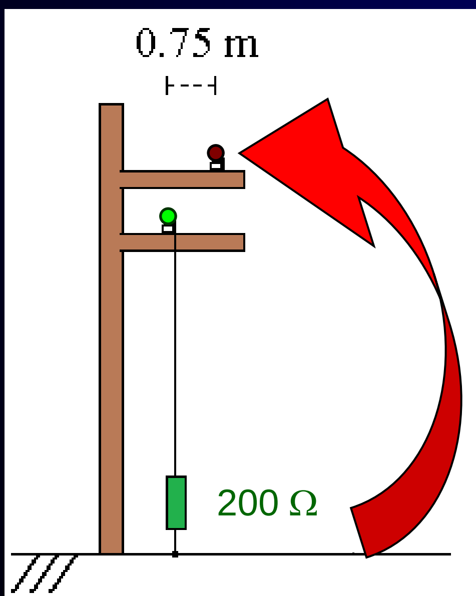
$$U(x,t)_{ERM(\rho \neq 0)} = U(x,t)_{ERM(\rho = 0)} + VEx_I(x,t)$$

Piantini (2017)

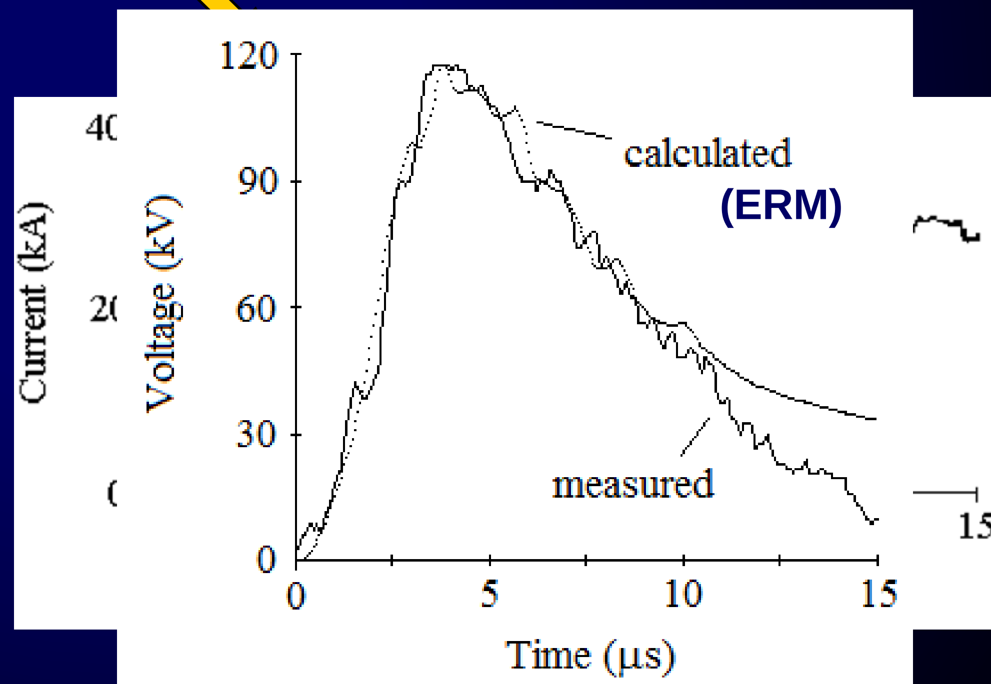
VALIDATION – ERM



Shield wire (or neutral)



1:50 scale model (USP)

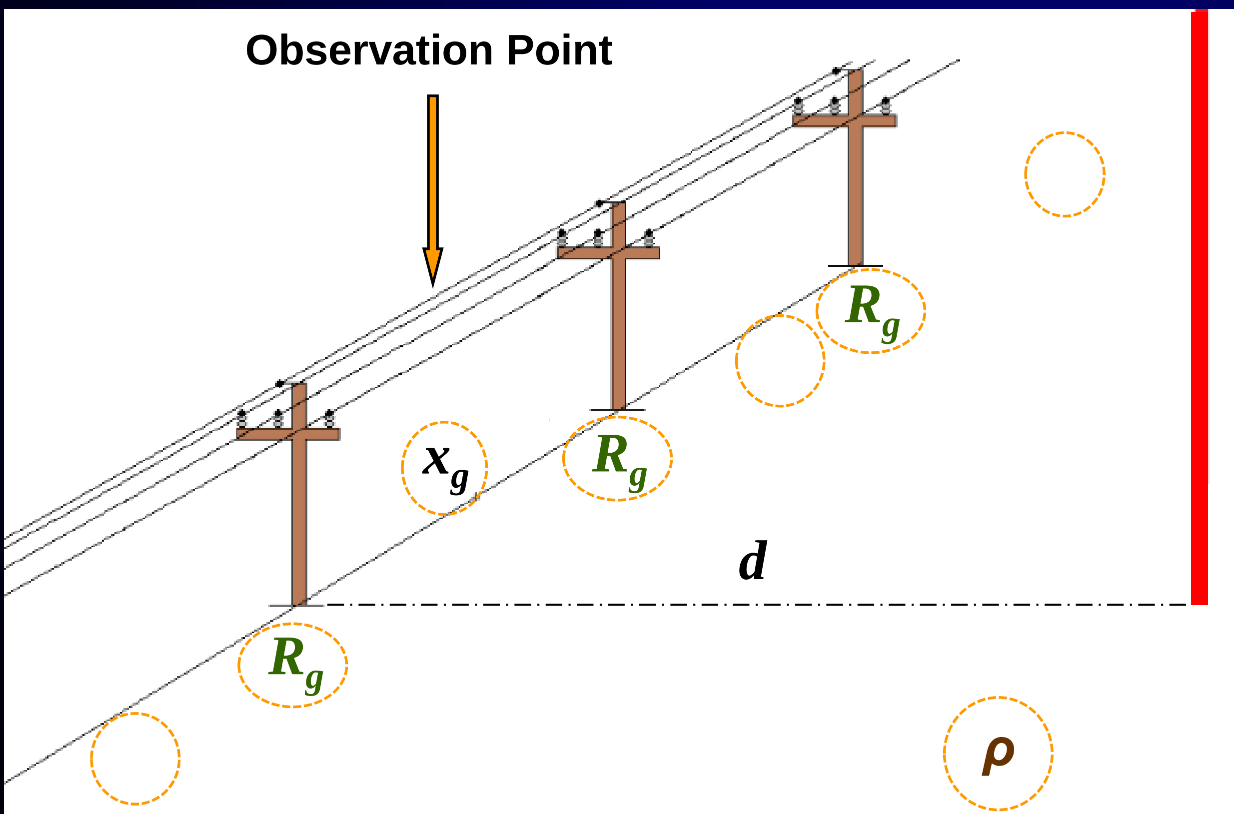


(All parameters referred to the full-scale system)

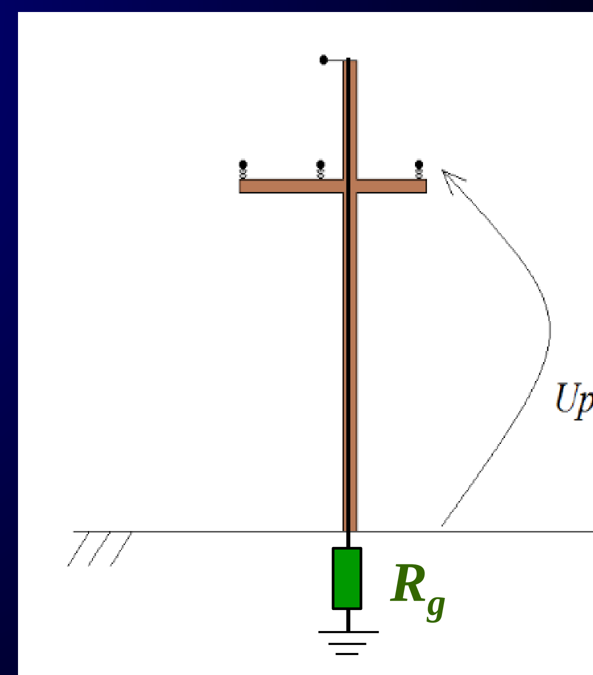
I = 36 kA; t_f = 3.1 μs; v_f = 0.11 c; hc = 600 m; h = 10 m; hg = 9 m; Rg = 200 Ω; ρ = 0 Ωm

To analyse the influences of the most important parameters on the SW effectiveness

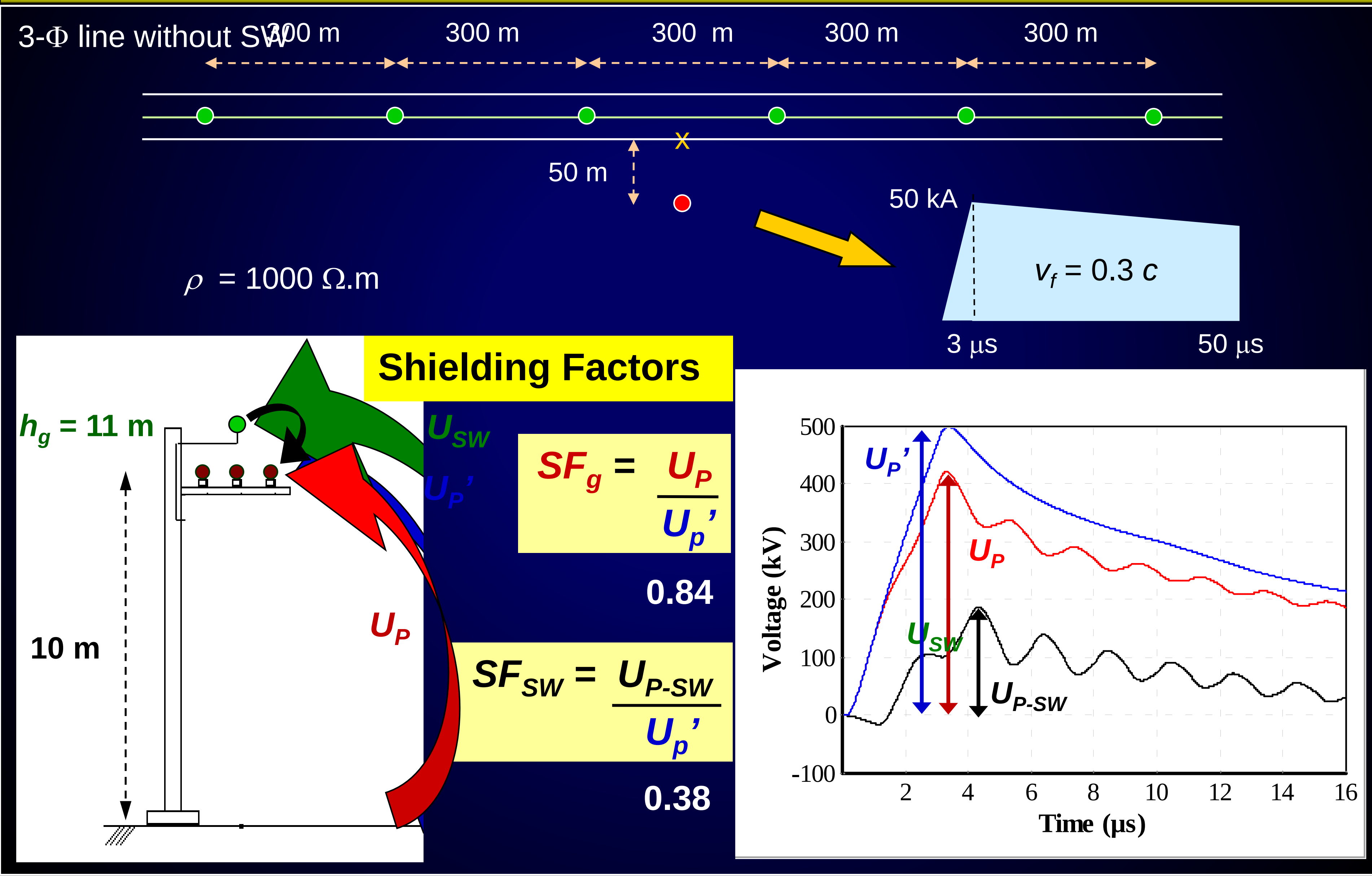
Basic line configuration: 3 phases + shield wire



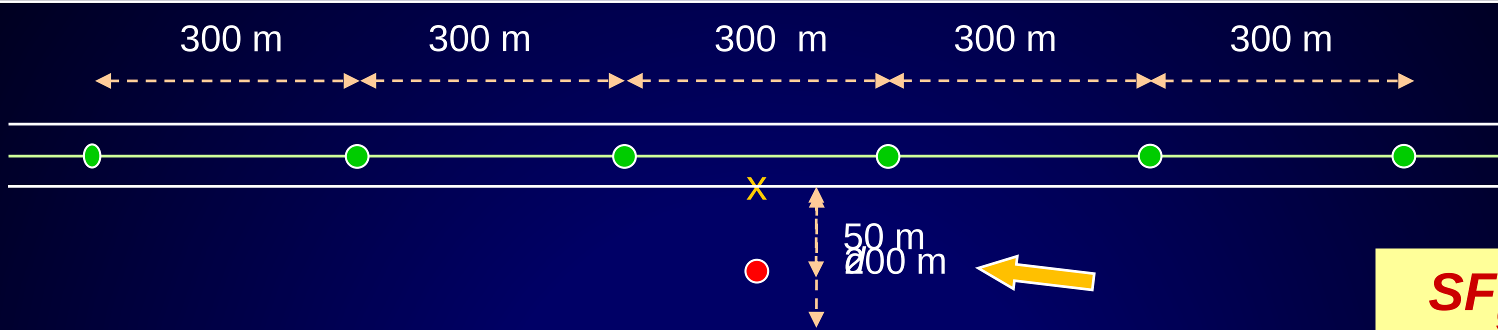
$I\ (t_f, v_f)$



SHIELDING FACTORS



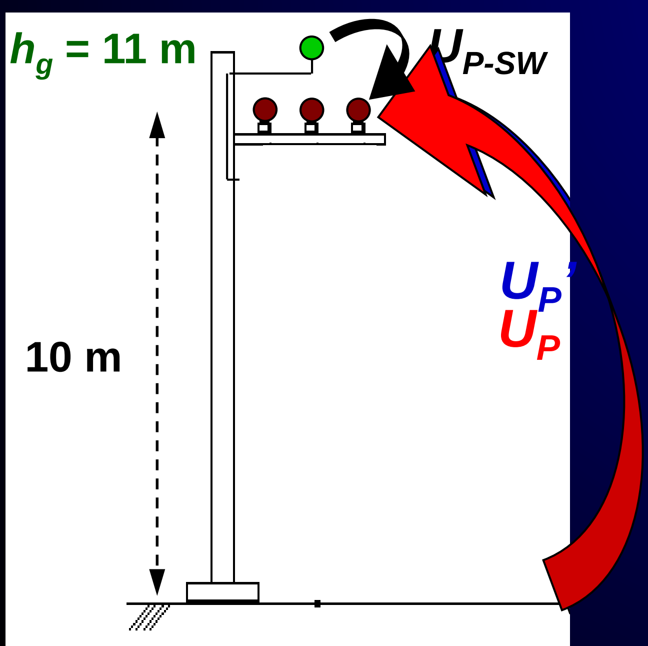
SHIELDING FACTORS *(Rg, ρ, d)*

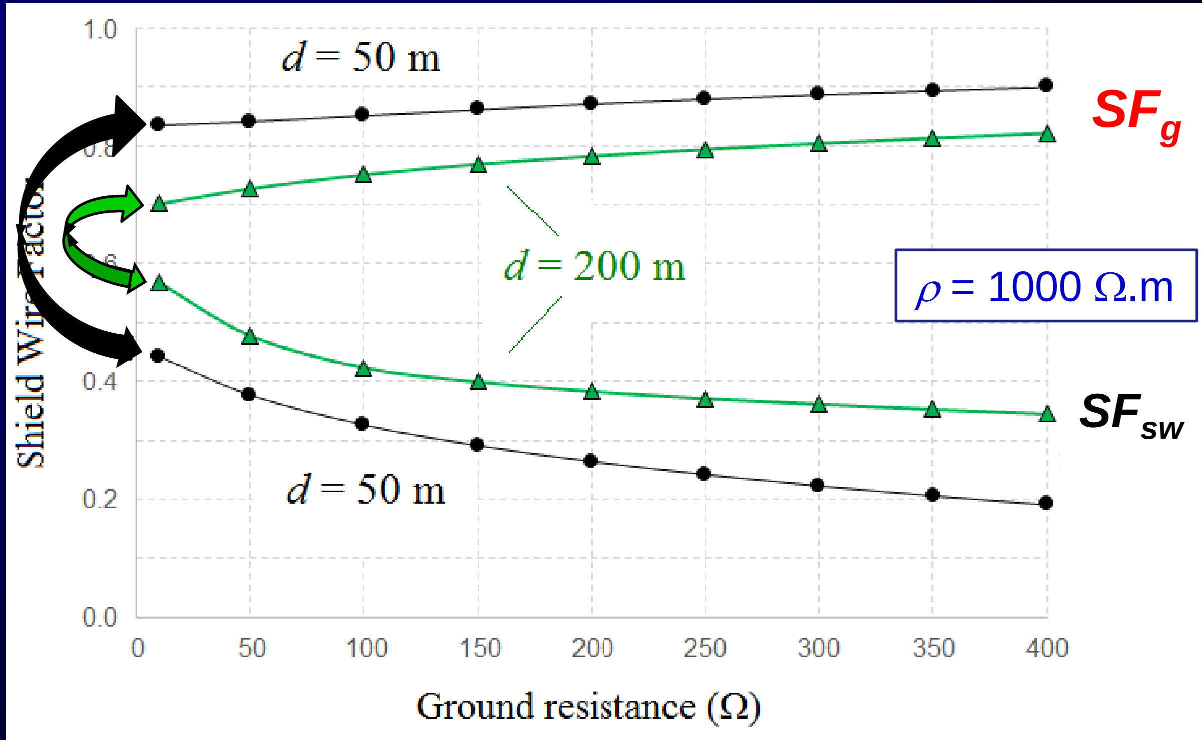


$$SF_{SW} = \frac{U_{P\text{-}SW}}{U_p'}$$

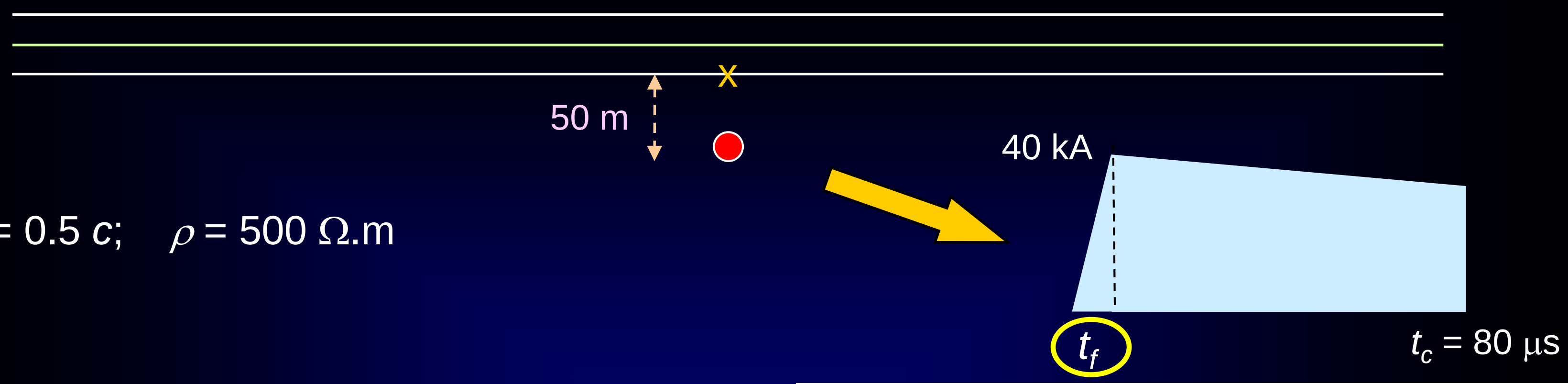
I = 50 kA; t_f = 3 μs; v_f = 0.3 c

$$SF_g = \frac{U_P}{U_p'}$$

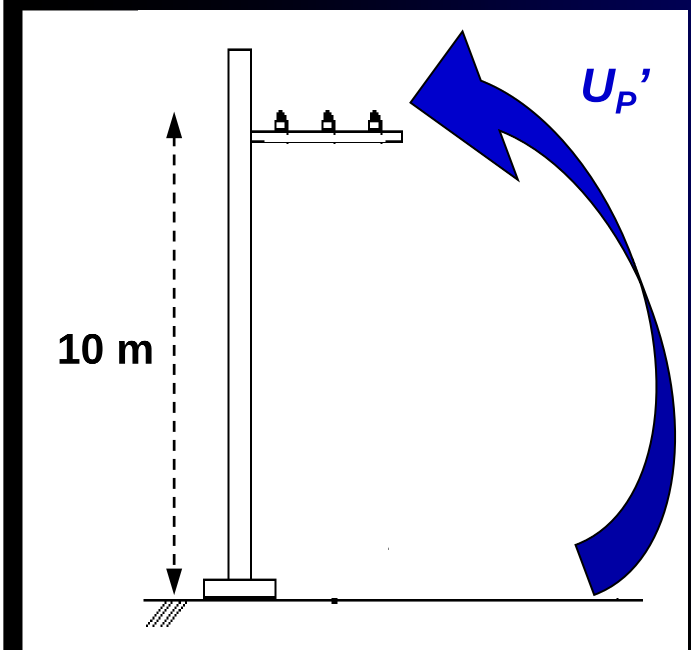


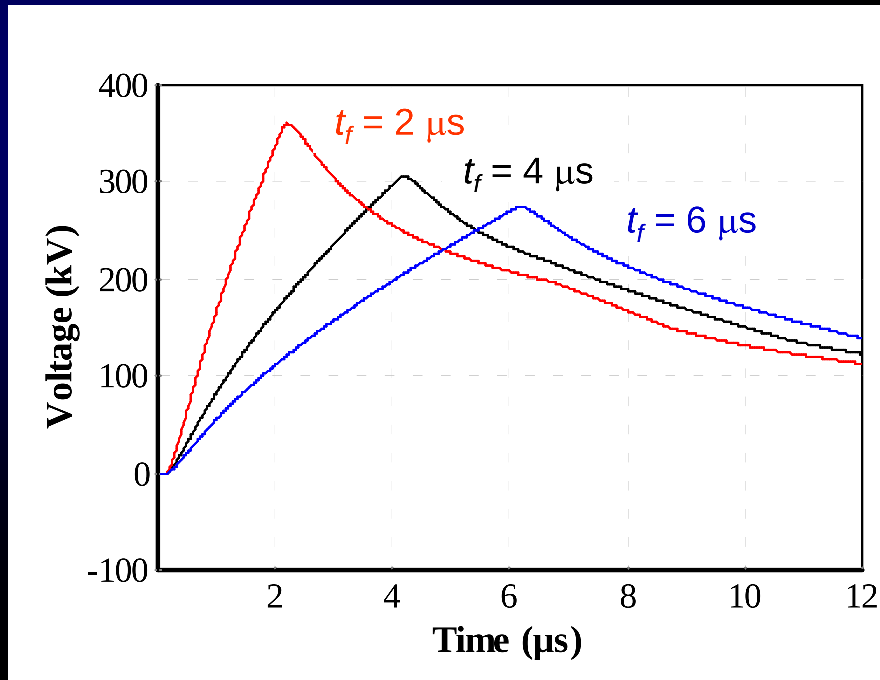


STROKE CURRENT FRONT TIME

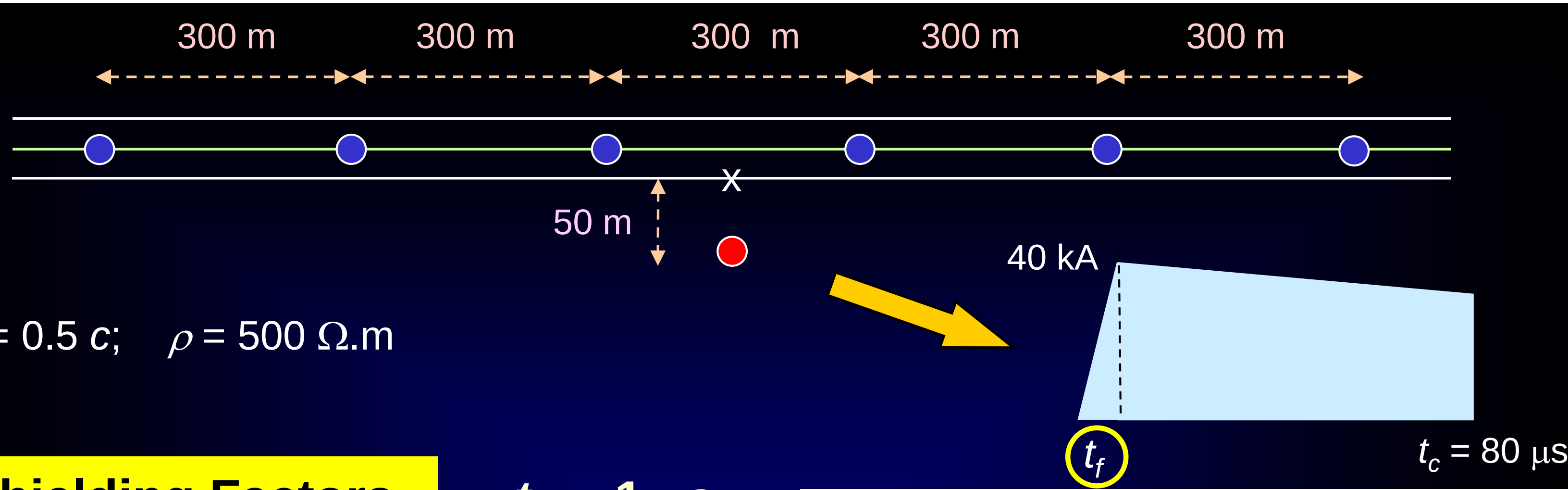


$v_f = 0.5\ c$; $\rho = 500\ \Omega.m$

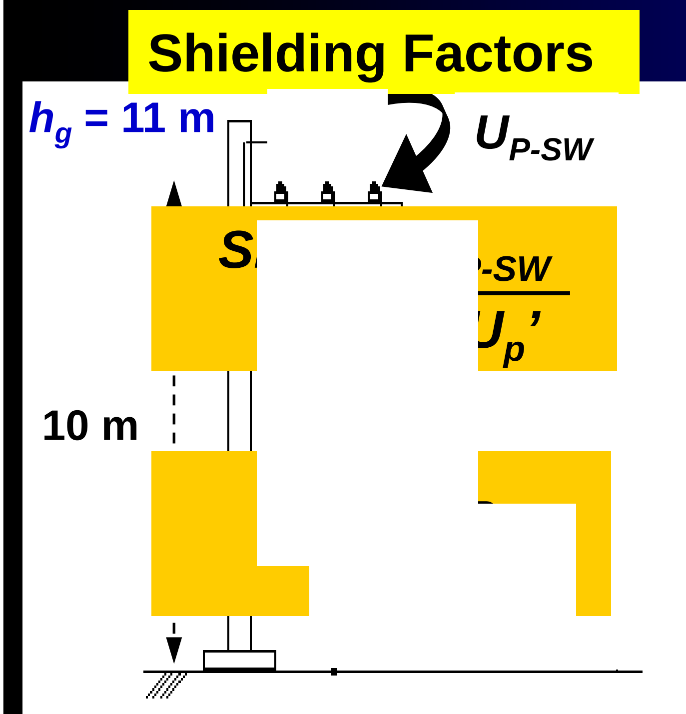




STROKE CURRENT FRONT TIME



$v_f = 0.5\,c$; $\rho = 500\ \Omega$.m

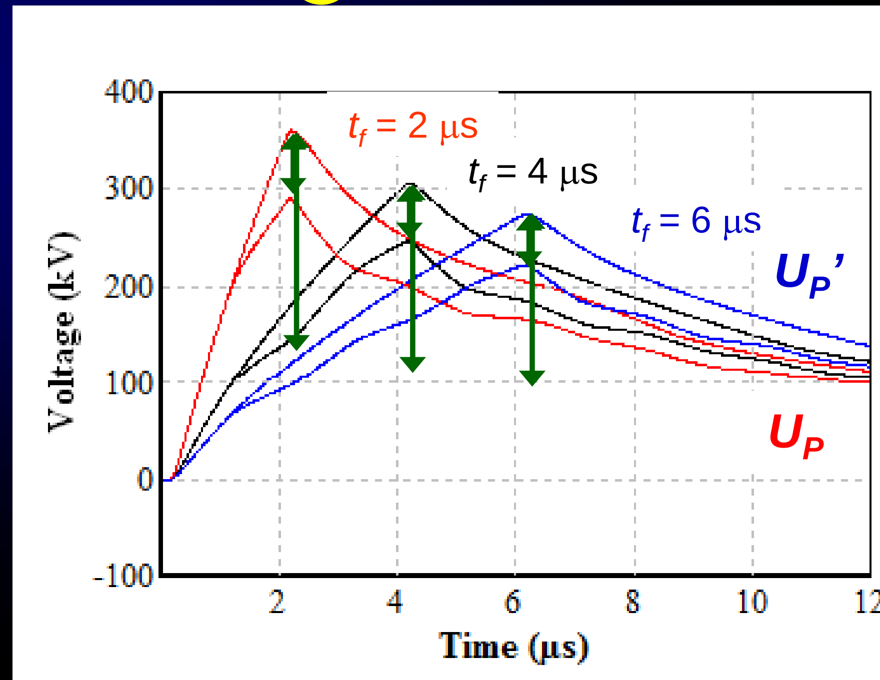


t_f = 1 µs

0.35.630.34

t_f ↑

≈0.981



CONCLUSIONS

- A SW can mitigate LIV and improve the LP of distribution lines. However, its effectiveness depends on several line and lightning parameters, as well as on ρ;
- SF_g and SF_{sw} are differently affected by such parameters;
- for the realistic situations considered, the SFs varied in the ranges of ≈ 0.65 to 1.0 (SF_g) and 0.2 to 0.7 (SF_{sw});
- although for high ρ and high R_g the effectiveness of the SW in ↓ P-G voltages is not significant, under such conditions its effectiveness in ↓ LIV between terminals of power equip. ↑;

CONCLUSIONS

- both SFs tend to ↑ when t_f ↓, this influence being more important in the case of short values; for t_f > few μs such influence tends to be relatively small;
- SF_g tends to ↑ slightly with v_f. A larger variation is observed on SF_{sw}, which has the opposite behaviour;
- the shorter the distance d, the lower the ↓ of the P-G voltages and the greater the ↓ of the P-SW voltages;
- an ↑ in ρ results in an ↑ in SF_g and in a ↓ in SF_{sw};
- both SF_g and SF_{sw} ↓ as h_g ↑;

CONCLUSIONS

- R_g may have a great effect on the LIV (esp. on the P-SW voltages), mainly when the channel is in front of a grounding point. SF_g ↑ with R_g (SF_{sw}: opposite behavior);

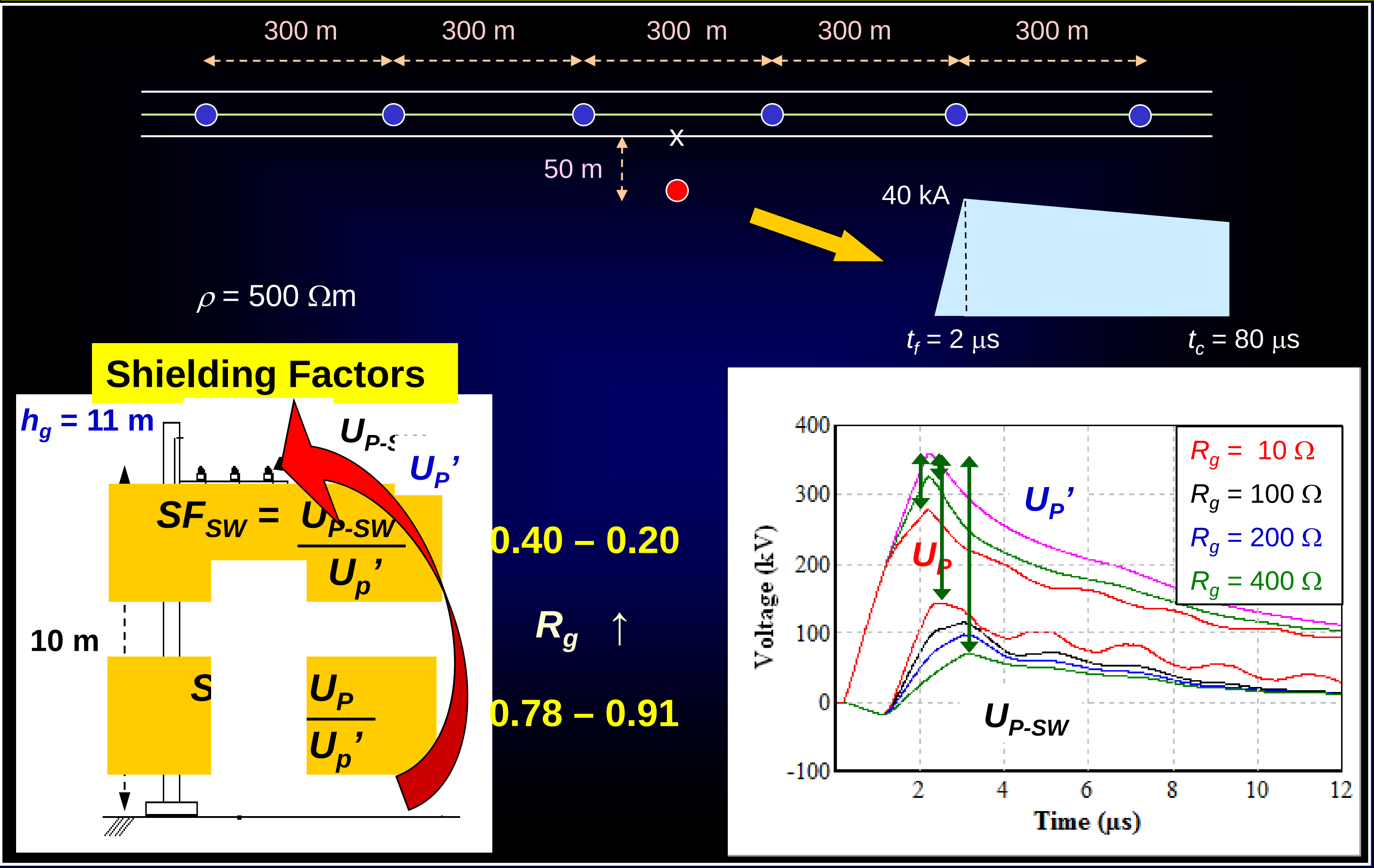
- SF_g ↑ with x_g, whereas SF_{sw} may either ↑ or ↓ with x_g, depending on the values of the other parameters. For R_g > a certain value, it tends to ↓ as x_g ↑. The opposite behavior is observed in case of low R_g values;

- relative position of the LC and SW groundings has a strong influence on the SFs, esp. in case of large x_g, low R_g, and/or currents with short t_f. ↓ R_g → ↑ influence.

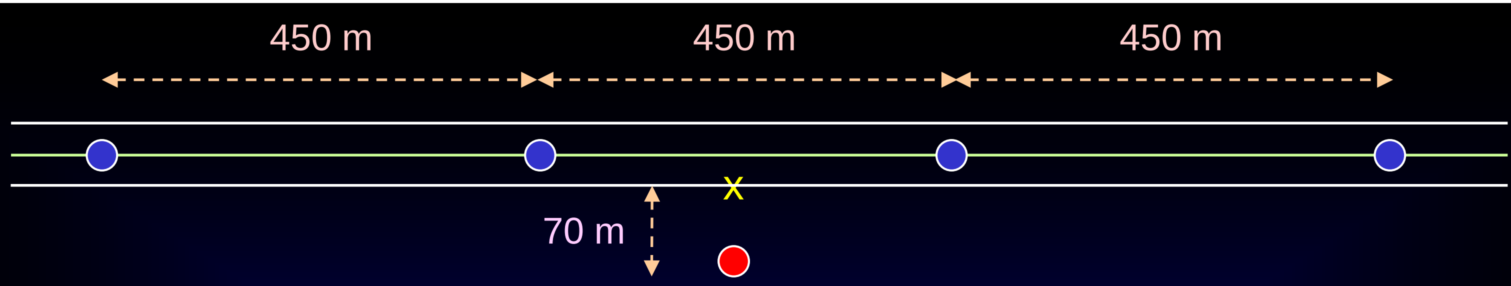
Благодарим за внимание!

THANK YOU FOR YOUR ATTENTION!

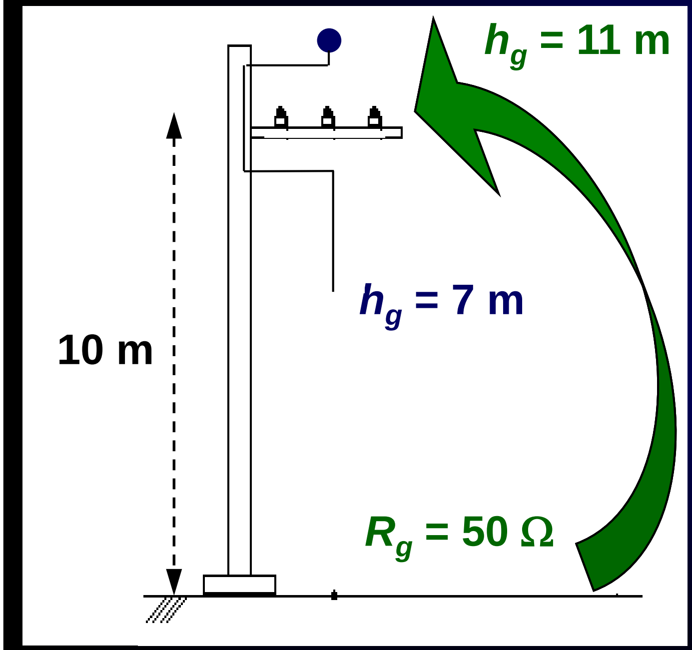
GROUND RESISTANCE

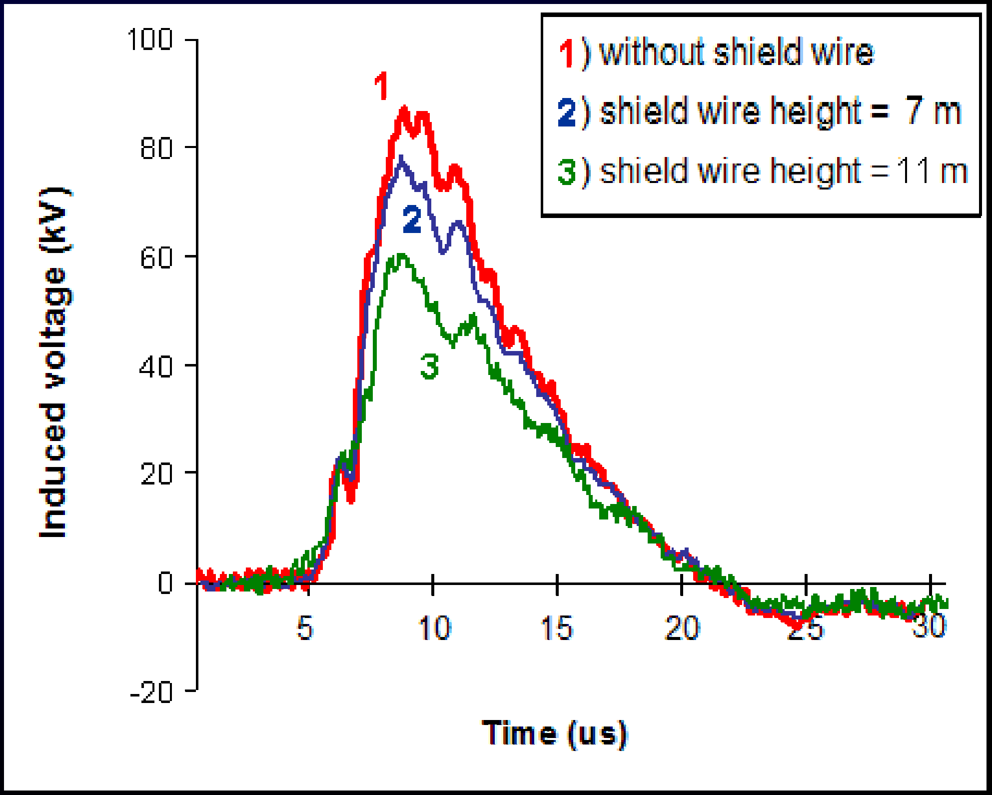


Shield wire height



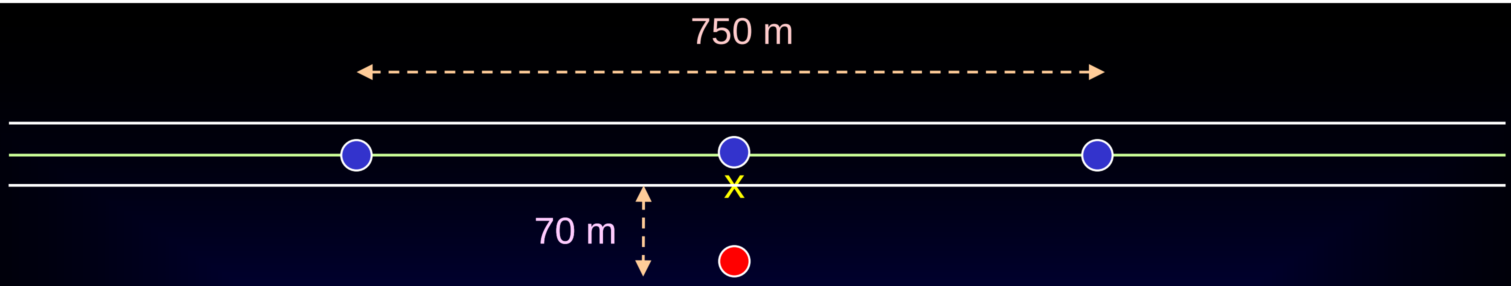
1:50 scale model, USP





I = 24.9 kA; t_f = 3.5 μs; ρ = 0 Ω.m

Shield wire – relative position



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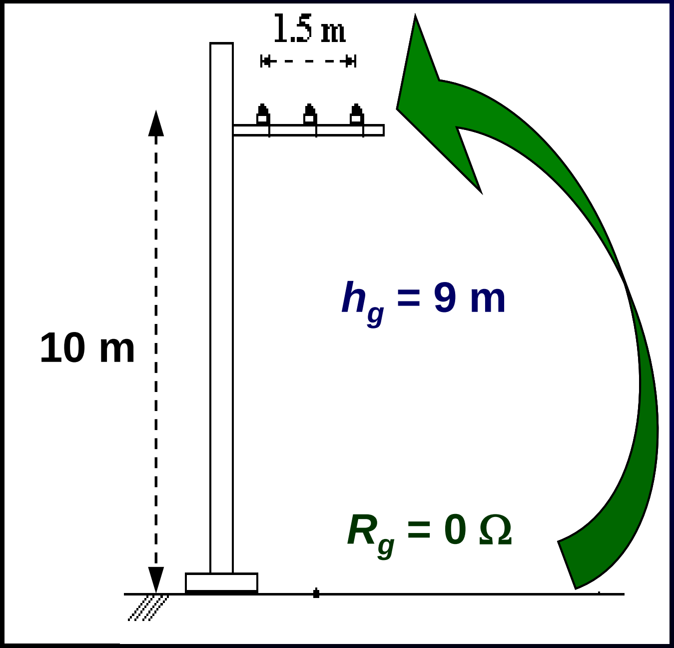

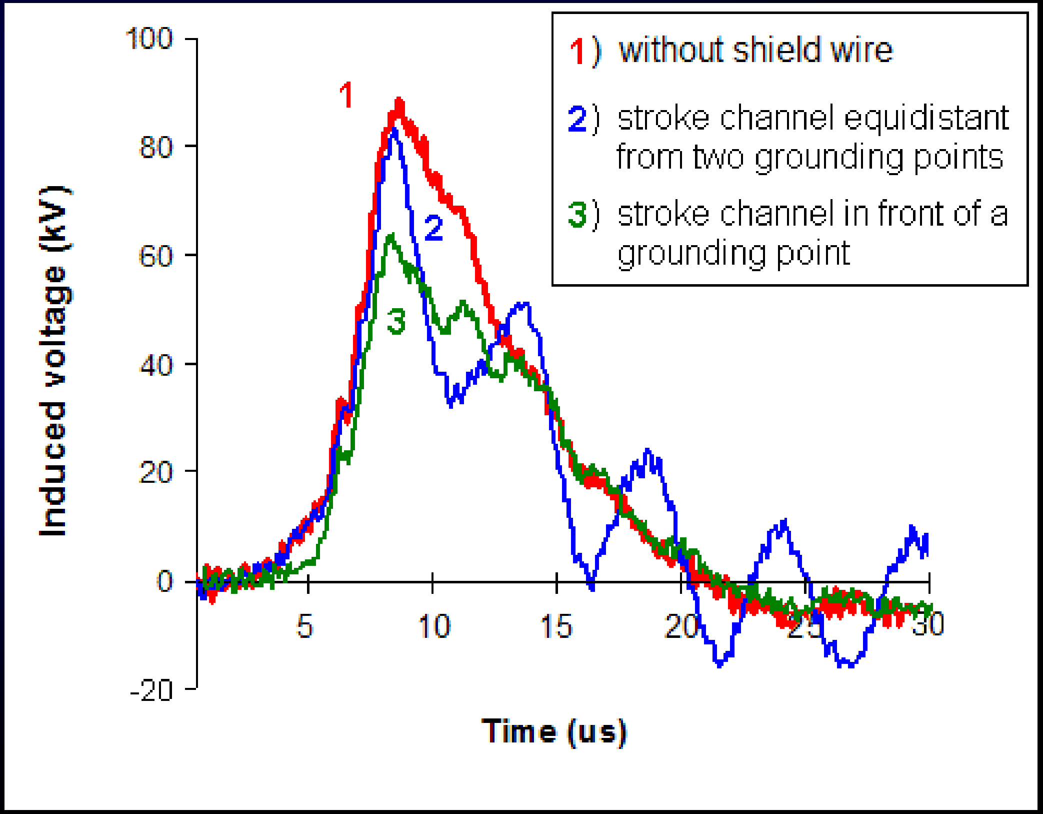

I = 24.9 kA; t_f = 3.5 μs; ρ = 0 Ω.m

INDUCED VOLTAGES (Scale Model)