GIC - Meeting
2nd February 2023

Shield Wires effect on GIC simulations

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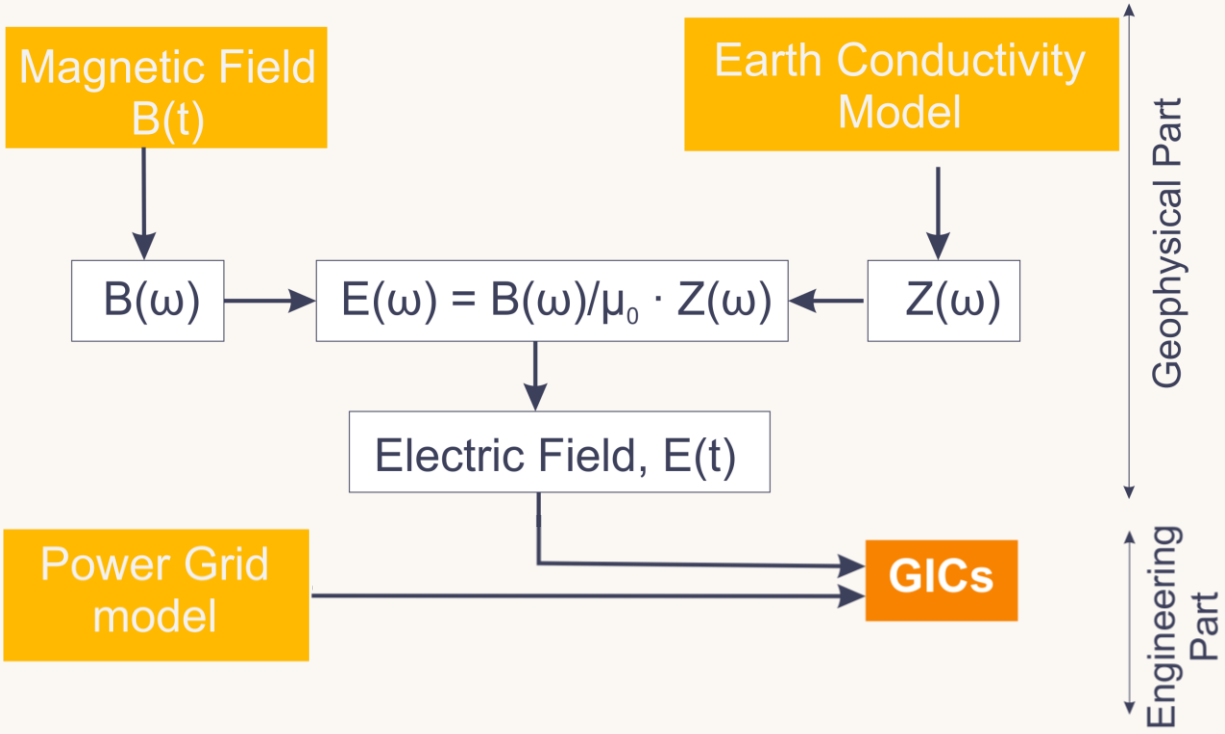
GIC computation

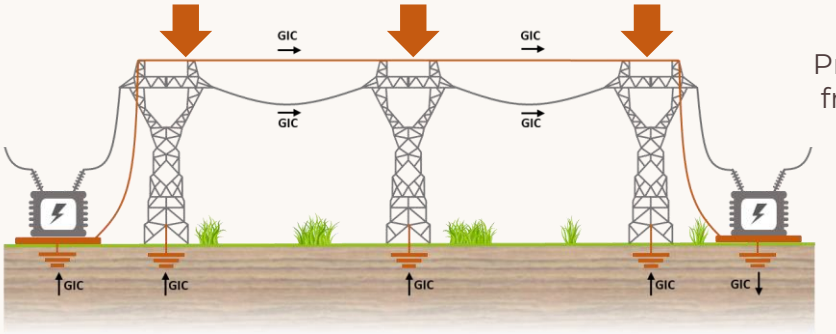


GIC computation

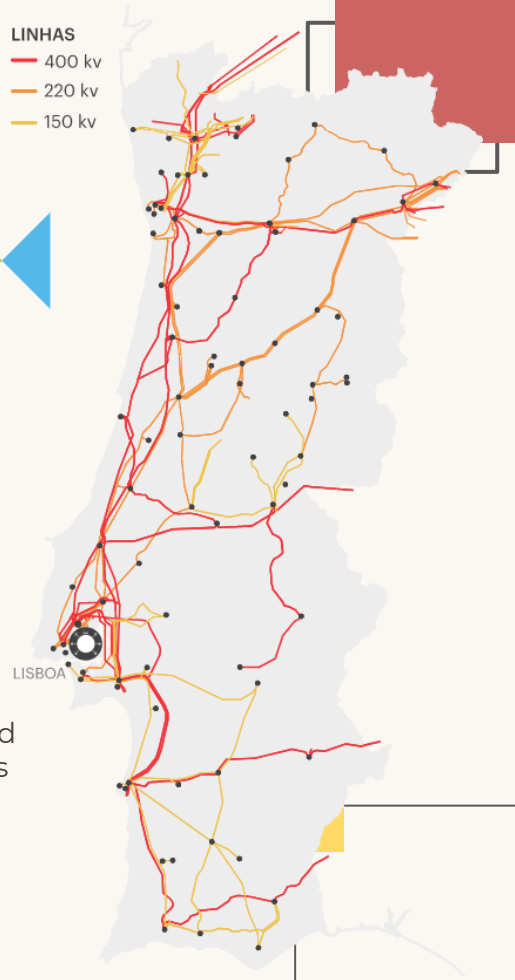
Power Grid model

- **Substations**
  (location and grounding resistance)
- **Power transformers**
  (type and winding resistance)
- **Transmission lines**
  (length and line resistance)

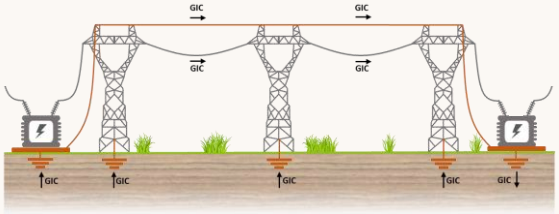
What about Shield Wires (ShW)?



Protect the power grid from lightning strikes



Literature review



Meliopoulos et al. (1994)

Different shield wire resistances lead to significant differences in the GIC intensity

Pirjola R. (2007)

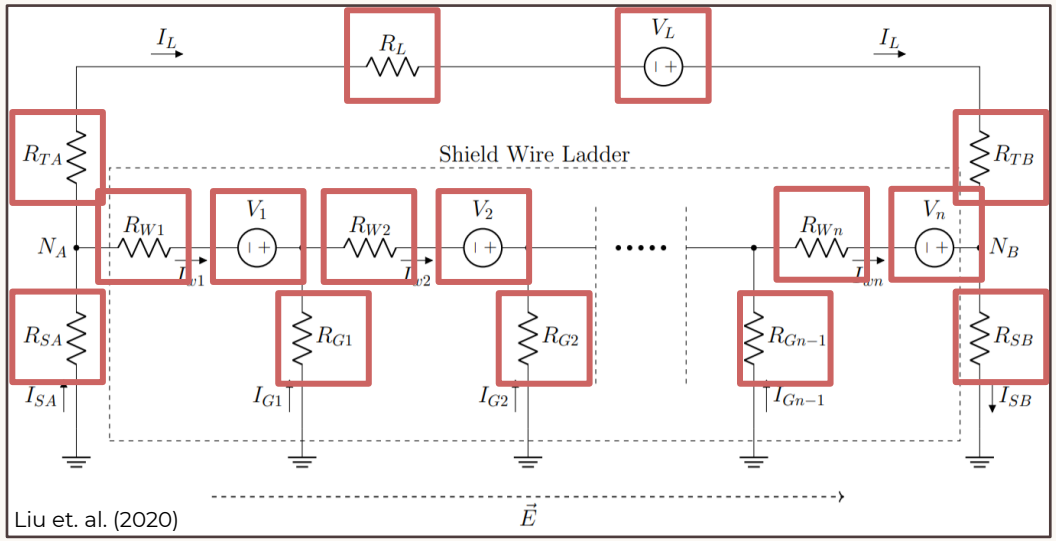
Due to small estimation values in the case of **long lines**, it was concluded that the **shield wire circuits needed not to be considered.**

Liu et al. (2020)

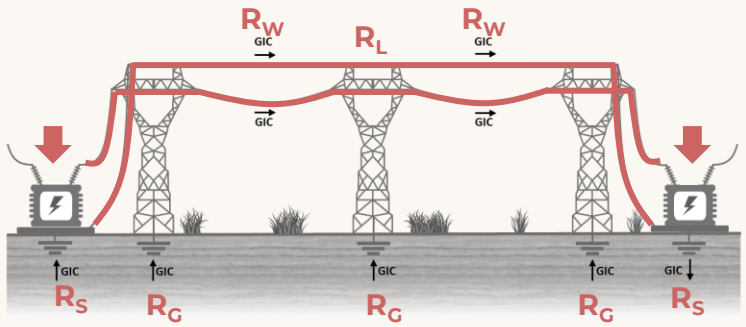
The shield wire effect would increase GICs by reducing the equivalent grounding resistances at substations

Santos et al. (2022)

Equivalent circuit for ShW

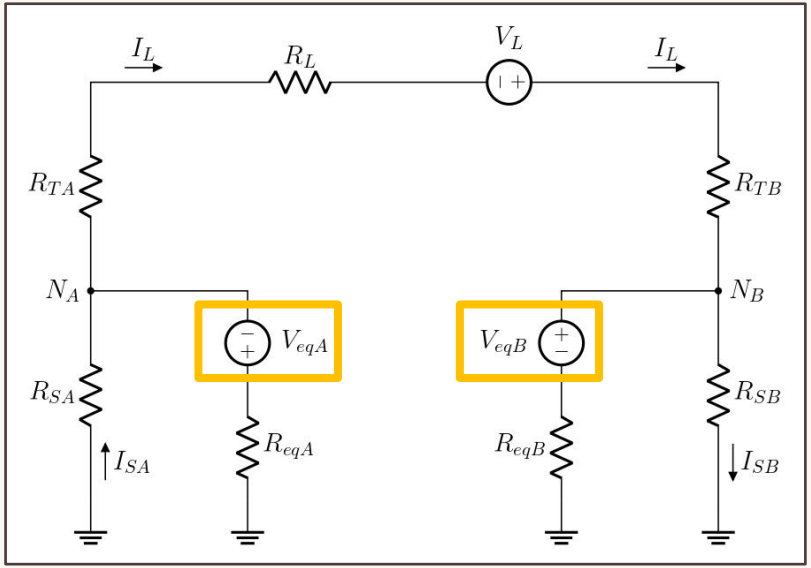


Liu et. al. (2020)



Can we simplify this circuit?

Equivalent circuit for ShW



Santos et al. (2022)

Equivalent circuit with both ShW resistances and electromotive forces (emfs) was obtained!

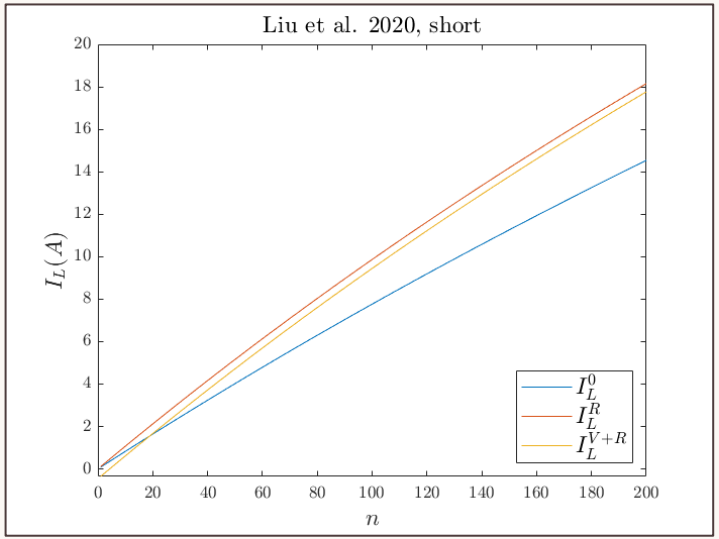
Asymptotic Expressions:

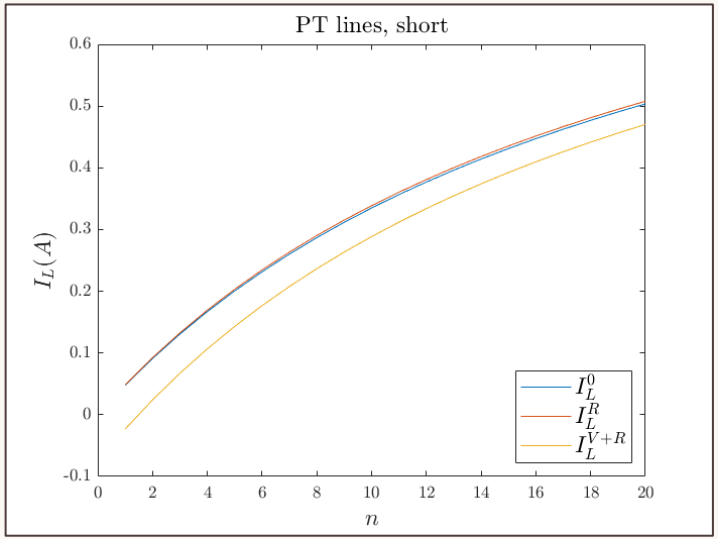
$$R_{eq} = \frac{R_W}{2} + \sqrt{R_W \cdot R_G}$$

$$V_{eq} = V_W \left[\frac{R_G}{\frac{R_W}{2} + \sqrt{R_W \cdot R_G}} + 1 \right]$$

What did we conclude?

1. The importance of including the **effect of ShW** in the calculation of **GICs depends on the power network parameters** (grounding resistance, transformer winding resistance, line length).

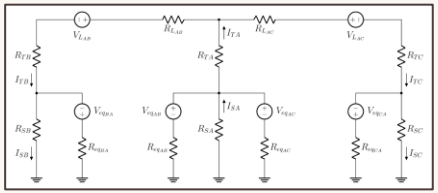


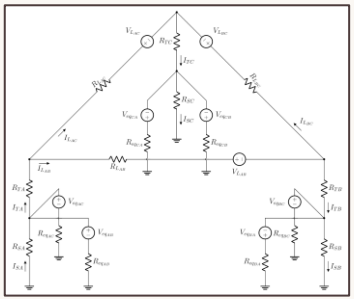


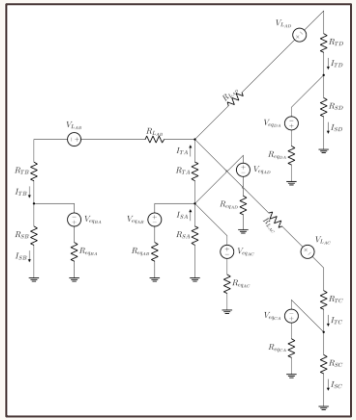
Without ShW **With only ShW resistances** **With both ShW resistances and emfs**

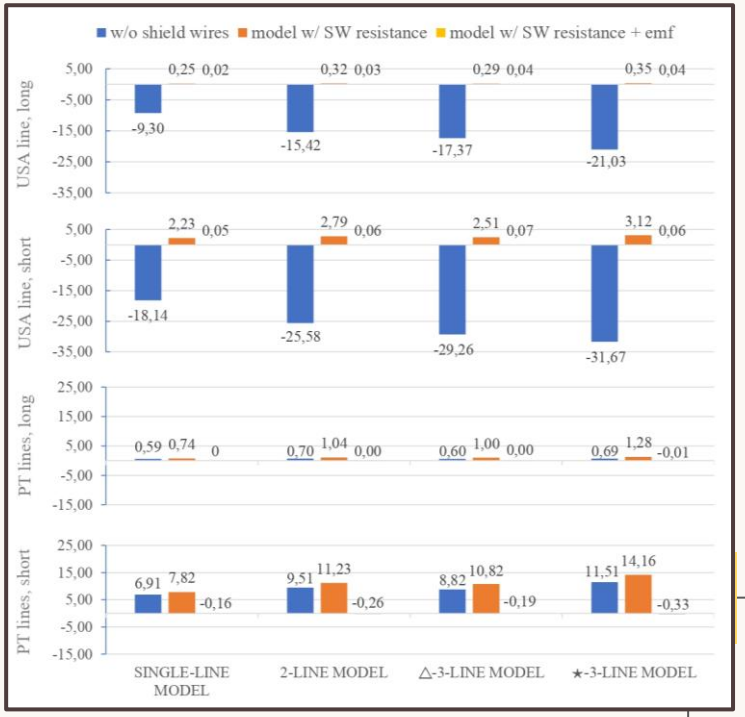
What did we conclude?

2. The **error** due to neglecting the ShW circuit **increases with complexity** (**blue bars increase with complexity**).









Complexity

What did we conclude?

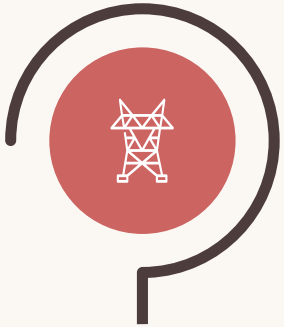
3. In the case of **short PT lines**,

   a) ShW protect transmission lines from GICs (**positive blue bar**).

   b) using only ShW resistance increases the error in GICs compared to neglecting ShW (**orange bar** higher than **blue bar**).

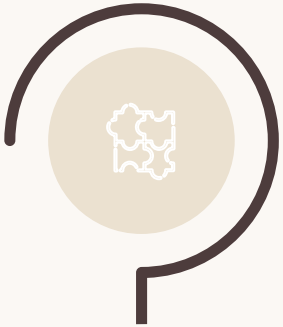
   c) For multiple connections, the **error may be larger than 10%** and the model here proposed eliminates it (last set of bars).

Results: Single-line model



Grid Parameters

Influence of ShW on GIC calculations depends on the power grid parameters



Complexity

The error due to neglecting the ShW circuit increases with complexity

Protective effect

For Portuguese lines, ShW decreases GICs

Preliminary

Results: Portuguese Power Grid

GIC simulations with

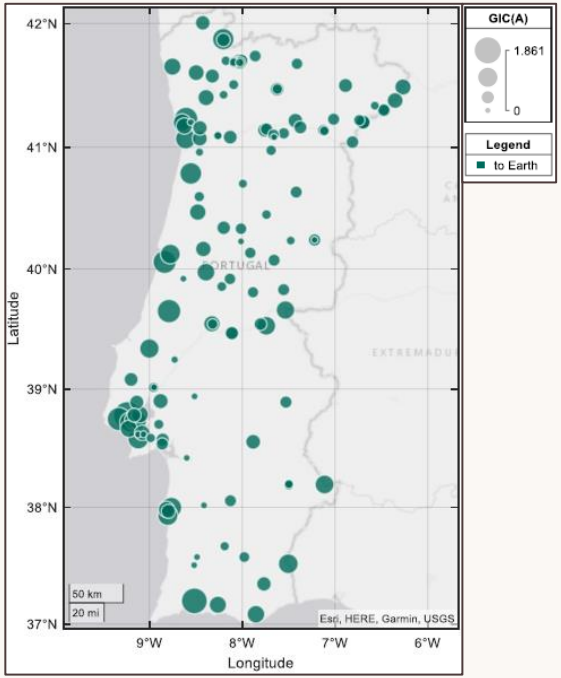
uniform conductivity model

$$E_{x,y}(\omega) = \pm\sqrt{\frac{i\omega}{\mu_0\sigma}}B_{y,x}(\omega)$$

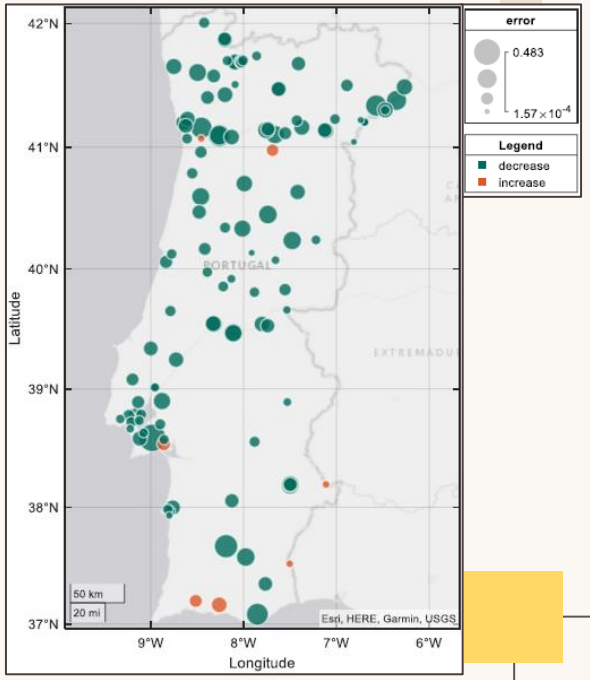
$$\boldsymbol{GIC(t) = GIC_N \cdot E_x(t) + GIC_E \cdot E_y(t)}$$

with the conductivity parameter (σ) fitted with **GIC observations**,

and GIC_N and GIC_E computed for each substation, using E = 1V/km



$\max(GIC_W)$** during the 17-18th September 2021 storm



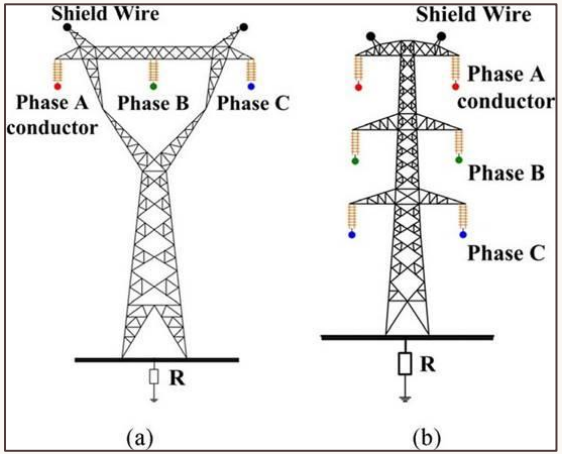
$$\Delta GIC = \frac{|GIC_w| - |GIC_{wo}|}{|GIC_w|}$$

** max(GIC) do not occour at the same time

Next steps

Realistic estimates of the shield wires effect

- Adaptation of the GEOMAGICA code
- Use induced electric fields based on 3D conductivity model (B-S model)
- Characterization of the shield wire circuit (number of shield wires per tower, number of shield wires in each substation)
- Compare with GIC measurements



Thank you!

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https://www.uc.pt/en/org/maggic

References

Meliopoulos, A. S., Glytsis, E. N., Cokkinides, G. J., & Rabinowitz, M. (1994). Comparison of SS-GIC and MHD-EMP-GIC effects on power systems. IEEE transactions on power delivery, 9(1), 194-207.

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