Realistic estimates of the shield wire effect on the Portuguese power grid

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Introduction

Geomagnetically Induced Currents (GICs) are electric currents that are induced in **transmission power networks** by oscillations of Earth's magnetic field that take place during **Geomagnetic Storms**. They can damage transformers and even lead to blackouts.

Shield Wires (ShW) are protective cables installed above the phase conductors, connected to the ground. Although ShW can carry GICs in the same way as the phase lines, they are generally **neglected in GIC simulations**. In this study, we analyze the effect of ShW on induced GICs.

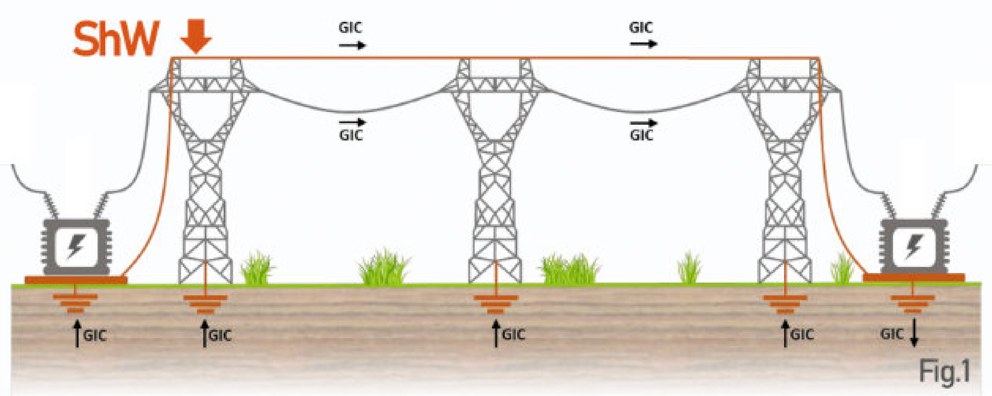

Fig.1

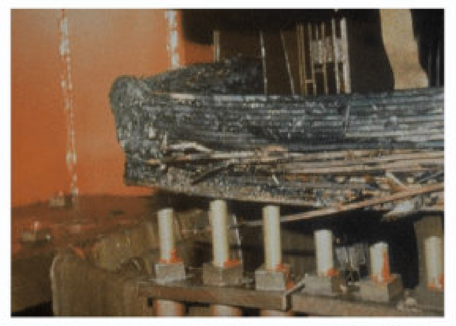
Melted transformer windings after March 1989 geomagnetic storm

Fig.2

New Jersey, Courtesy of PSE&G

GICs through transformers increase 15% when considering ShW

Methodology

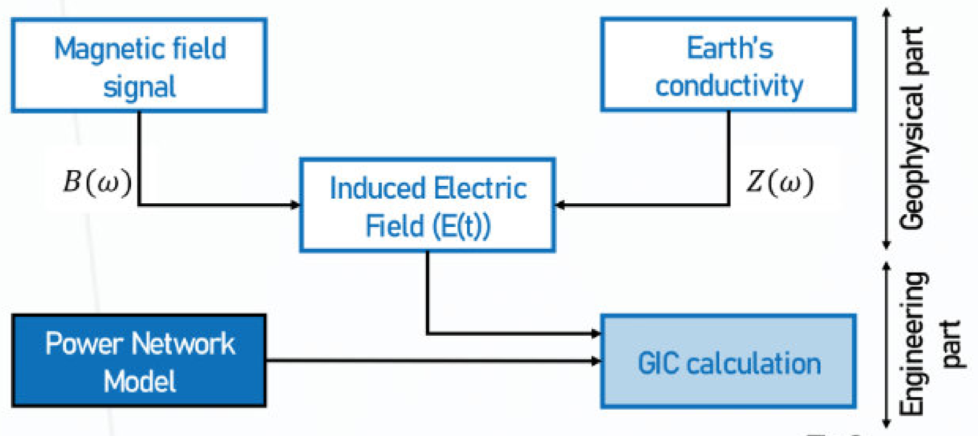

Fig.3

We added ShW to the power network circuit and used a realistic conductivity model obtained from inversion of MT soundings. In the end, we observe that:

Results

GIC estimates flowing through substation **decrease** ~40%

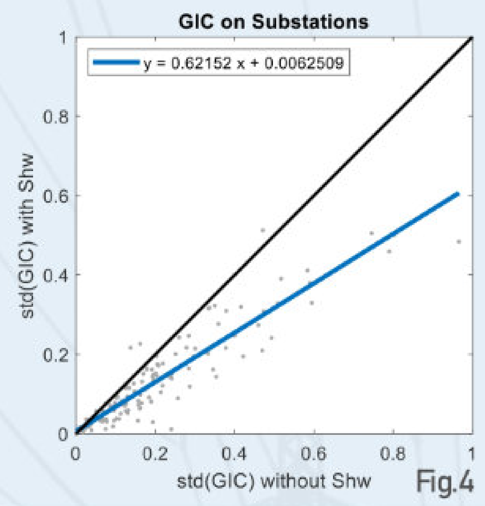

Fig.4

GIC estimates flowing through transformer windings **increase** ~15%

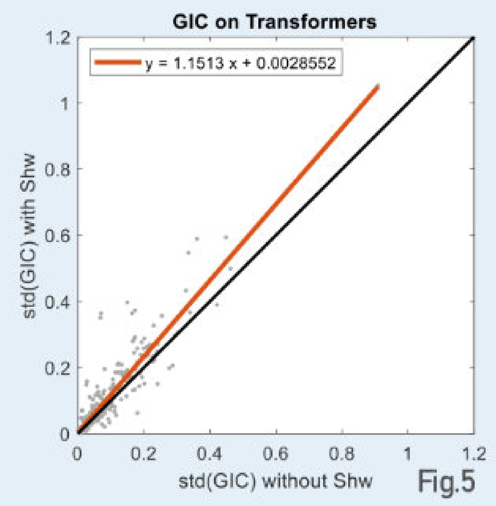

Fig.5

Plot of the transformer's maximum GIC difference $\left(\frac{\Delta I_{GIC}}{I_{GIC}}\right)$ in each substation when considering ShW ($\Delta I_{GIC} = I_{GIC}^{with\ ShW} - I_{GIC}$).

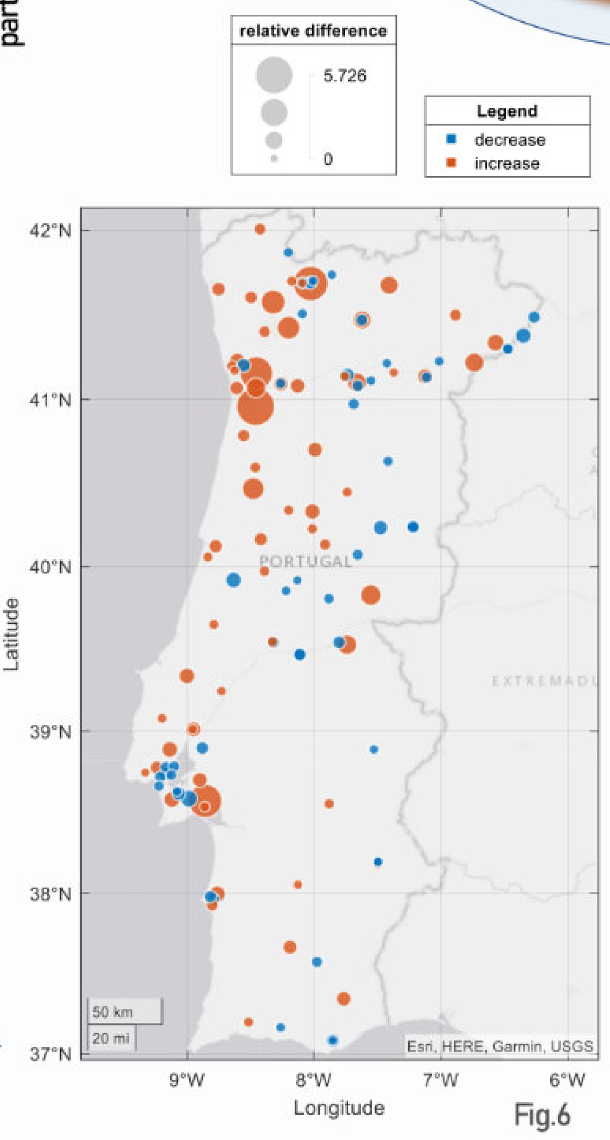

Fig.6

Analysis

The impact of ShW on the computed GICs through transformers is globally a slight increase of ~15% (see Fig 5). Nonetheless, at individual substations, there can be a decrease or an increase (Santos et al., 2022). From Fig 6, the increasing effect of ShW is more significant in the north where the ground is more resistive (higher substations' grounding resistance (R_S)).

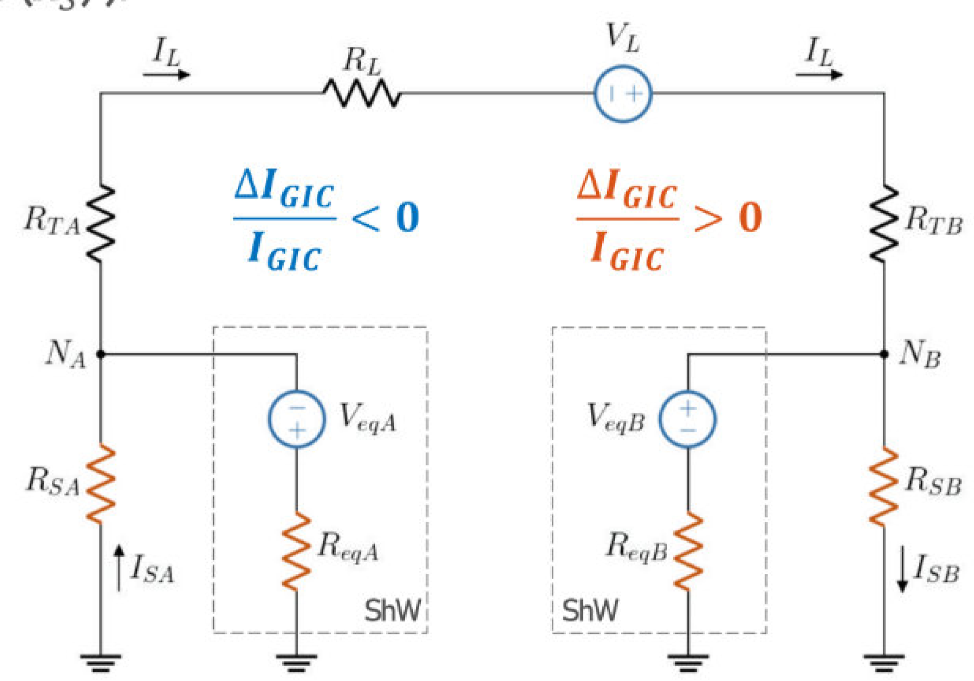

Fig. 7

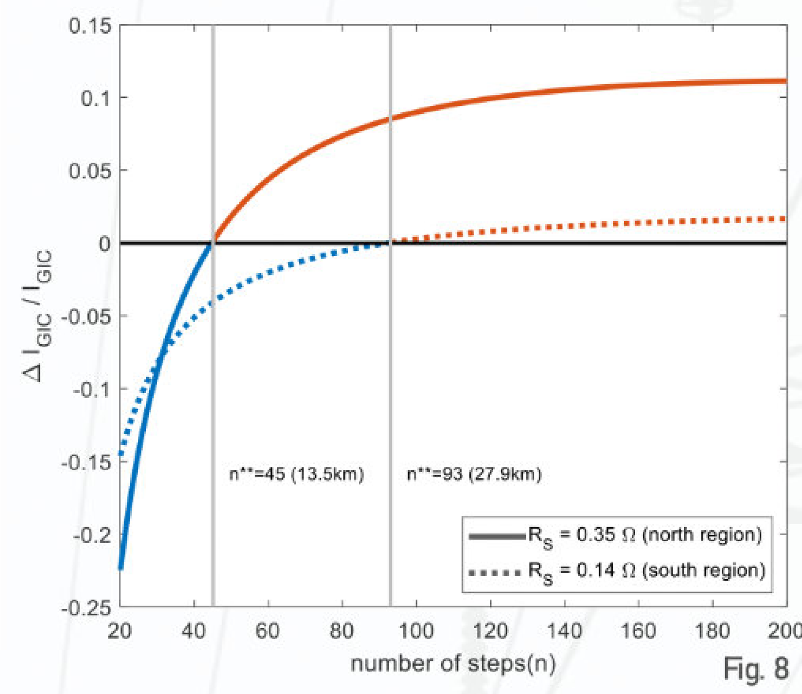

Fig. 8

The n^{**} value is the critical tower number above which the ShW effect changes from decreasing to Increasing GICs. From Fig. 8, the north region, which has higher R_S, has a lower n^{**} compared with the south. The average value of the Portuguese lines is 30 km; in the north region, this value largely overrides the n^{**} value there and the increase effect of ShW dominates.

Conclusions

- Adding ShW in GIC calculations has **opposite effects on substations grounding resistors and transformer windings**, as it reduces GICs in the former but increases them in the latter.
- Based on the **single-line model analysis**, the higher substation grounding resistance (R_S) in the north region results in a predominance of the **increasing effect of ShW on GICs**, whereas the lower R_S in the south region contributes to a **balance between the two effects.**
- However, this analysis does not consider **the variability of other parameters**, such as the line resistance per length (R*). Fig. 9 shows that for higher R*, the decreasing effect of ShW on GICs predominates. Additionally, in a **more complex network**, with many lines converging at a substation, the increasing effect of ShW on GICs prevails due to the decrease in equivalent grounding resistance.

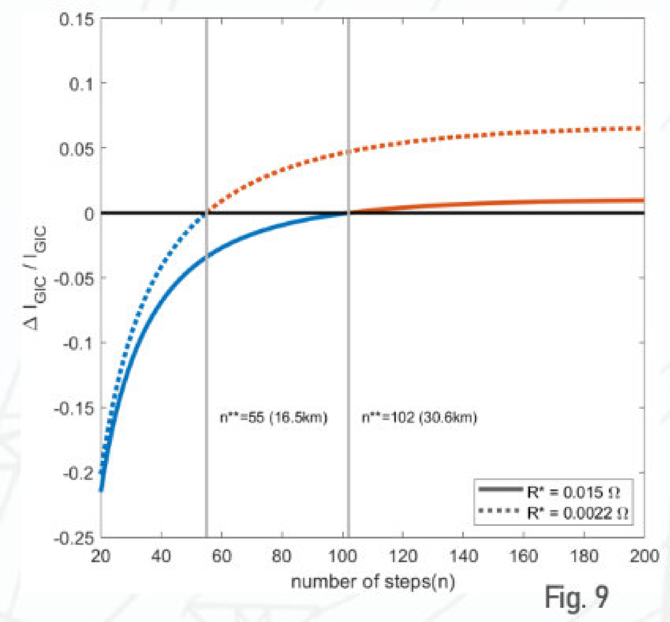

Fig. 9

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Santos et. al. 2022