Geomagnetic induced currents in south-western Iberia

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Abstract

Geomagnetic storms induce electric fields along power lines, which are the source of GICs observed at high latitudes. However, there have been accounts of GICs in mid-latitudes. For this reason, countries such as Spain, Italy and Brazil are evaluating the impact of GICs in their territory. Portugal is also giving its first steps in this field. MAG-GIC is a project funded by the Portuguese Science Foundation (FCT) aiming to assess the potential hazard of GICs on the national high voltage power grid. This project involves a collaboration with REN - the Portuguese power distribution company.

In this study, we show how to use the geomagnetic fields generated in the Portuguese mainland during some of the strongest geomagnetic storms recorded at University of Coimbra’s geomagnetic observatory (LGA code: COI) during solar cycle 24. This analysis takes into account impedance matrices computed from local magnetospheric (MT) observations. The geomagnetic observations were complemented with simulations from the Tsyganenko-Sitnov TS04 model, which can separate the contribution of different magnetospheric current systems, giving a better insight of the phenomena involved. Additionally, we provide our first estimations of the expected GIC values based on the real distributions of transformer stations located across the Portuguese South-West (the region with the sparsest distribution of transformer stations).

1. Introduction

Geomagnetic field disturbances (B) and ground resistivities play a key role in the generation of the GICs driving electric fields (E). As is known since Tikhonov (1950) and Cagniard (1953), the 1D induced field can be expressed:

\[ E = \frac{1}{\omega} \mathbf{a} \times \mathbf{Z} \mathbf{a} \]

where \( \mathbf{a} \) is the MT impedance of the Earth. Compared to the 50Hz high voltage AC current, GICs behave like a quasi-direct current. Thus the computation of GICs can be reduced to solving an electric circuit problem, using Kirchhoff laws (Lighthill & Pirjola,1985):

\[ \mathbf{GIC} = (1 + \mathbf{Y}^{-1}) \mathbf{J} \]

where \( \mathbf{Y} \) is the source admittance matrix and \( \mathbf{J} \) the current impendence matrix. The “perfect-earthing” currents generated along a grounded conductor (J) are computed from the integration of the electric field along its path.

2. Resistivity model

To compute \( \mathbf{Z} \), we will use MT results from Santos et al. (2003) and bathymetric data of the Portuguese coast (see fig. 1) as input for the 3D ModEM algorithm (Kollett et al. 2014). As a first approximation, \( \mathbf{Z} \) is the MT impedance of a 1D conductivity model (see fig. 2, left) and the DigitalEarthLab.com MT algorithm has been used to obtain an estimate for the apparent resistivity \( \rho_a \) (fig. 2, right). This approach is not realistic, mainly because of the proximity to Coimbra, the earthing impedance matrix. The “perfect-earthing” currents generated along a grounded conductor (J) are computed from the integration of the electric field along its path.

3. Geoelectric field

Given the small size of Portugal mainland and overall proximity to Coimbra, the geomagnetic variations recorded at the COI observatory are well suited to characterize the geoelectric fields induced in the south of Portugal. Figure 3 shows the geomagnetic variations during the March 2015 St. Patrick’s Day storm. The induced geoelectric field taking into account the 3D resistivity model has been computed (fig. 4), which involves only 400 kV and 150 kV lines. The current impendence and resistivity matrices, as well as the current vector, were computed using a 1-second sampled data and assuming a 1D conductivity model.

4. Power network model

The information required to characterize the Portuguese high voltage power network was provided by REN - Redes Energéticas Nacionais, SGPS, S.A.. We started by analyzing a substation model including all transformers, shunt reactors and the network admittance matrix and 1D conductivity model. The “perfect-earthing” currents generated along a grounded conductor (J) are computed from the integration of the electric field along its path.

5. Preliminary GIC model

Our model was tested against Horton’s (2012) benchmark. Figure 5 shows the GIC amplitudes generated at each transformer station, assuming normalised geoelectric fields of 1V/km in the North-South and East-West directions. Results for SMR, SER, SAV, STVR are unreliable, as these stations are connected to other nodes not included in the calculations (substations further north and/or connected to substations in Spain). Portugal substations (SPO) seem to be the most susceptible to GICs, which makes it a high candidate to connect a GIC sensor to test our model (see poster p11 in this session).

6. Sensitivity to network parameters

Values for grounding resistances at substations are necessary for GIC calculations. We verified that using the true values provided by REN brings significant changes to GICs, at some substations (fig. 6).

7. GIC during St. Patrick’s Day storm

Figure 7 shows the GIC amplitude at the Novo-Corvo (NYC) station during the St. Patrick’s Day storm.

8. Conclusions

- We present the first GIC simulations for the South of Portugal, using data from the national high voltage power network.
- We evaluate the impact of some electric network parameters on the intensity of GICs.
- From the subset of transformer substations that were evaluated, Portimão seems the most sensible to storms. This makes it a good candidate for GIC local monitoring.
- Further tests will be conducted, with a more realistic 3D conductivity model.

References


Acknowledgements

FCT

This work is funded by national funds through FCT - Foundation for Science and Technology, I.P., under project MAG-GIC (PTDC/CTE-CTM/31714/2016). The authors also acknowledge technical support from different members of the community (M.J. Tavares, M. Blae, A. Rigato, R. Pirjola, D. Bitterer, C. Lin et al.).