

MAG-GIC - Geomagnetically induced currents in Portuguese mainland

The MAG-GIC Collaboration:

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Paulo Ribeiro, João Cardoso***

UL/IDL: Fernando Santos, Miguel Miranda

Students: C. Francisco, R. Rebbah (UC), P. Soares (IDL)

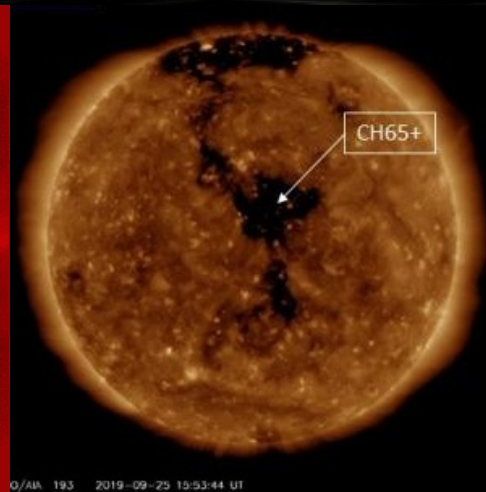
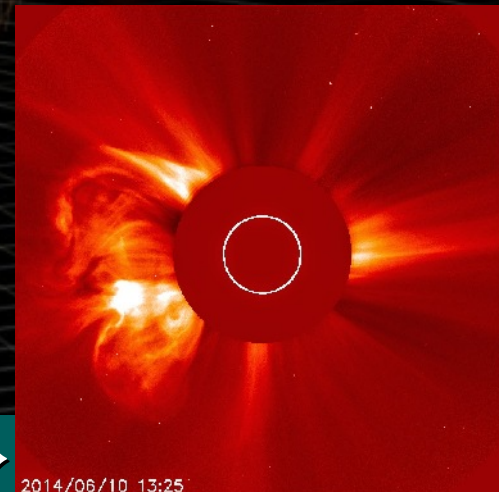
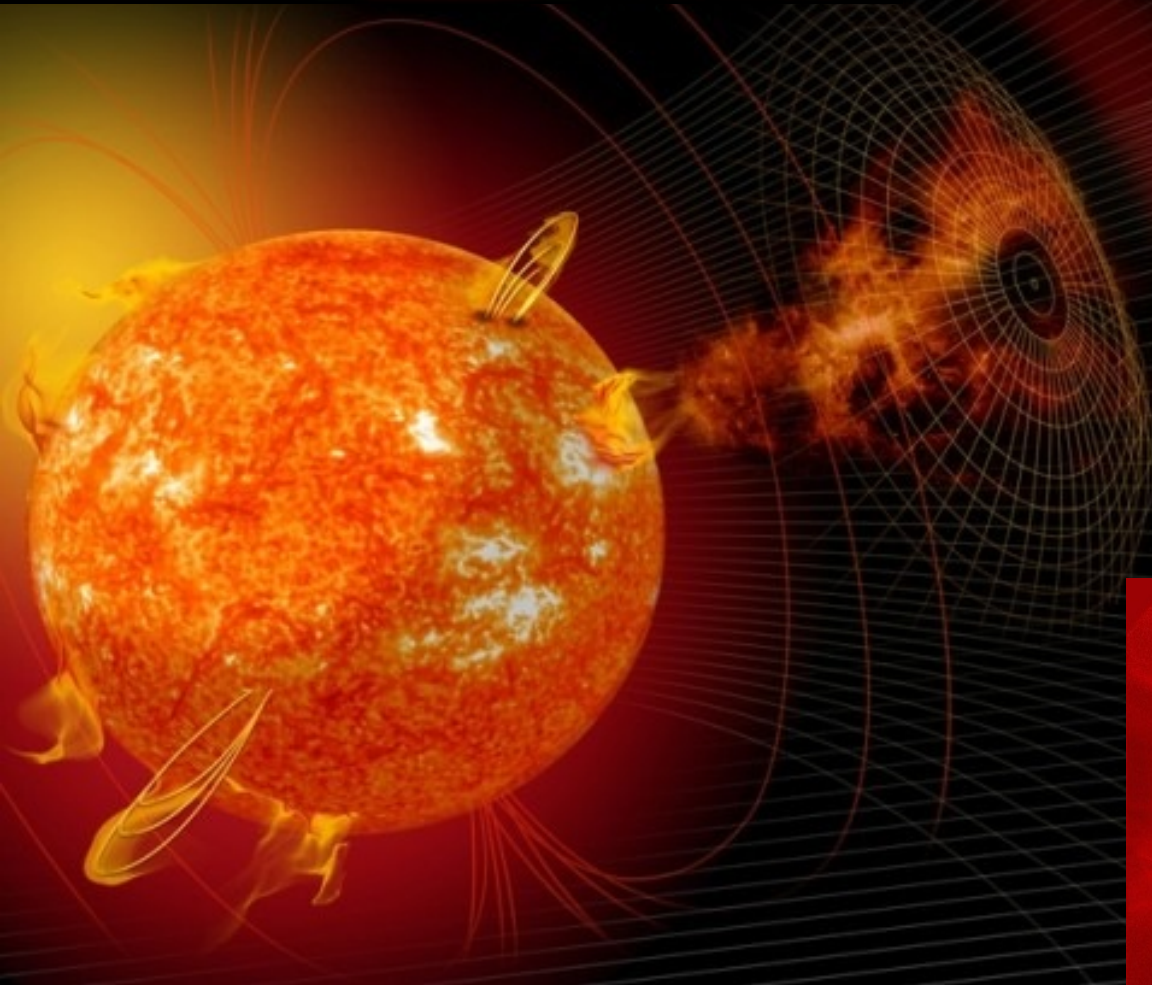


Cofinanciado por:



The origin of geomagnetic storms

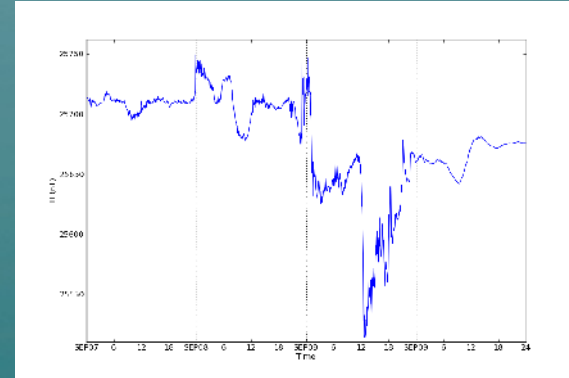
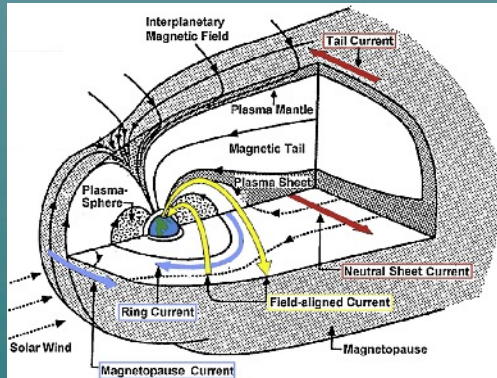
← Sun's ~11yr solar activity cycle



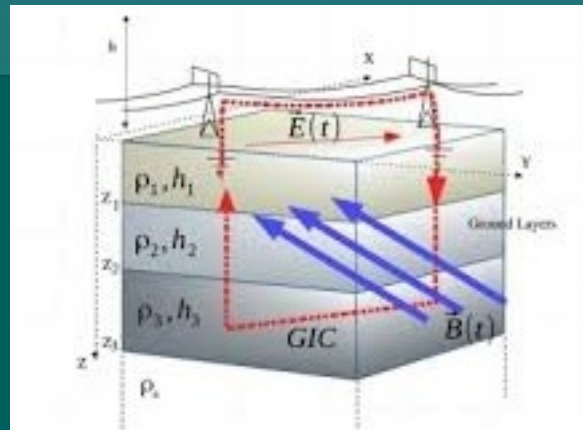
Particles from CMEs & Coronal Holes →

Geomagnetic storms & GICs

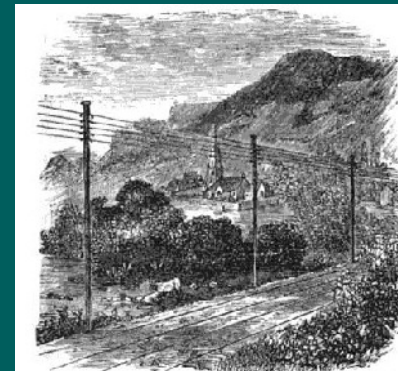
Solar particles and IMF field interact with magnetosphere



Oscillations in the geomagnetic field generate electric fields → thus currents can travel through grounded conductors → GICs



GIC accounts in telegraph lines:
UK (1847), Iberian Peninsula (1903)



Impact in the Power Network

- Saturate the power transformers' cores
- Introduce harmonics in the network
- Loss of reactive power
- Mechanical vibration in transformers
 - overheating
 - destruction of insulation oil
 - damage transformers
- Power blackouts
- e.g.: Hydro-Québec 3/1989,
Sweden & South Africa 2003



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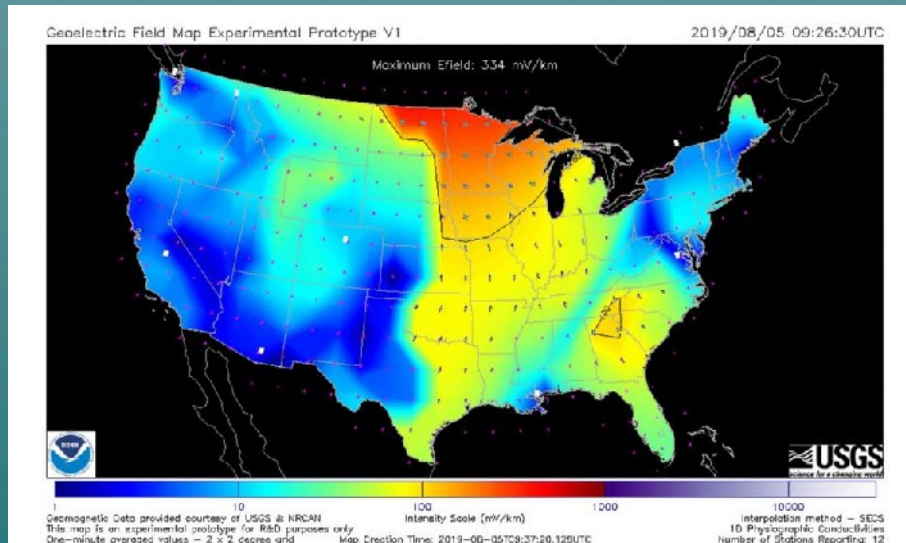


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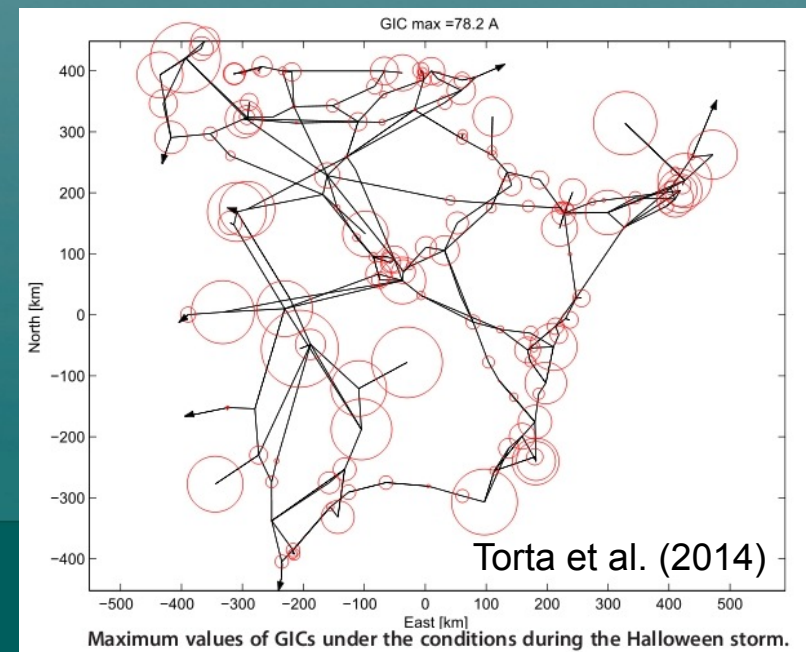
GICs studies worldwide:



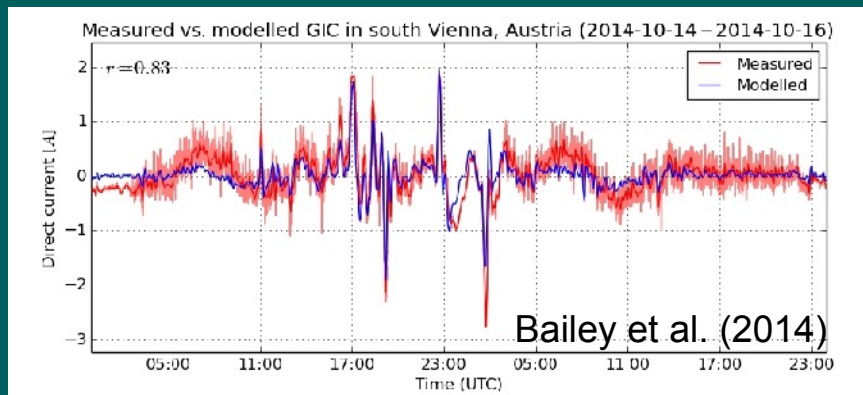
What is done worldwide?



E-field maps



Maximum GICs in the power network during a storm



GIC measurements
& modeling

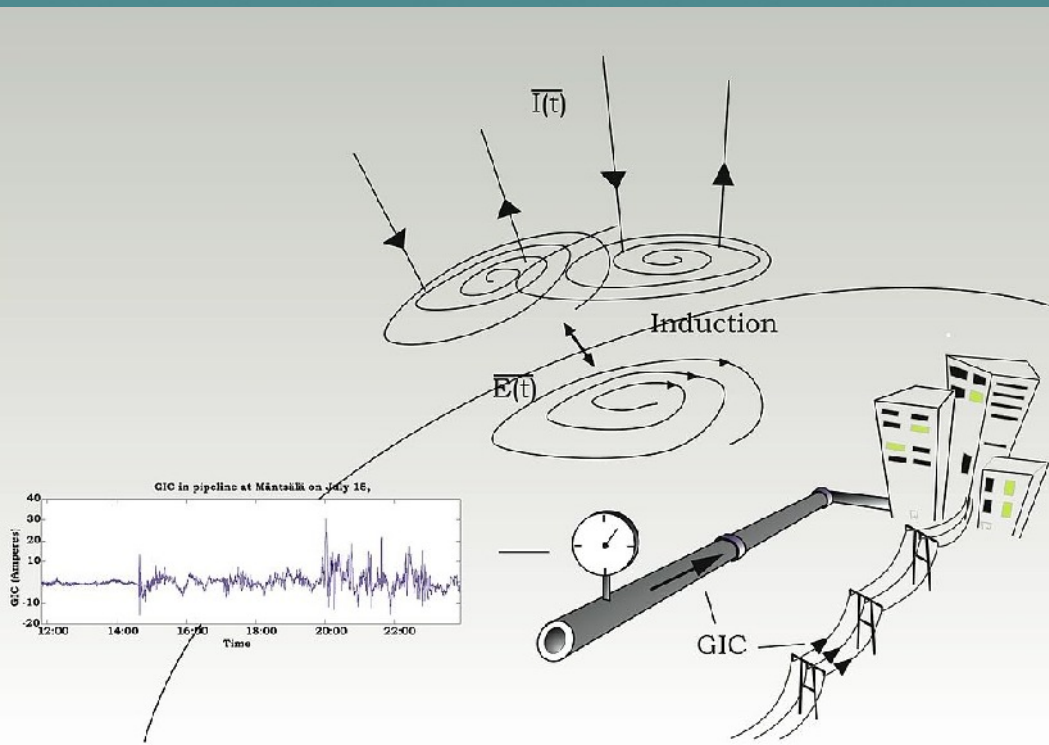
What about Portugal?

The MAG-GIC project

FCT 2017 R&D call for technol. develop. projs.

Main goals:

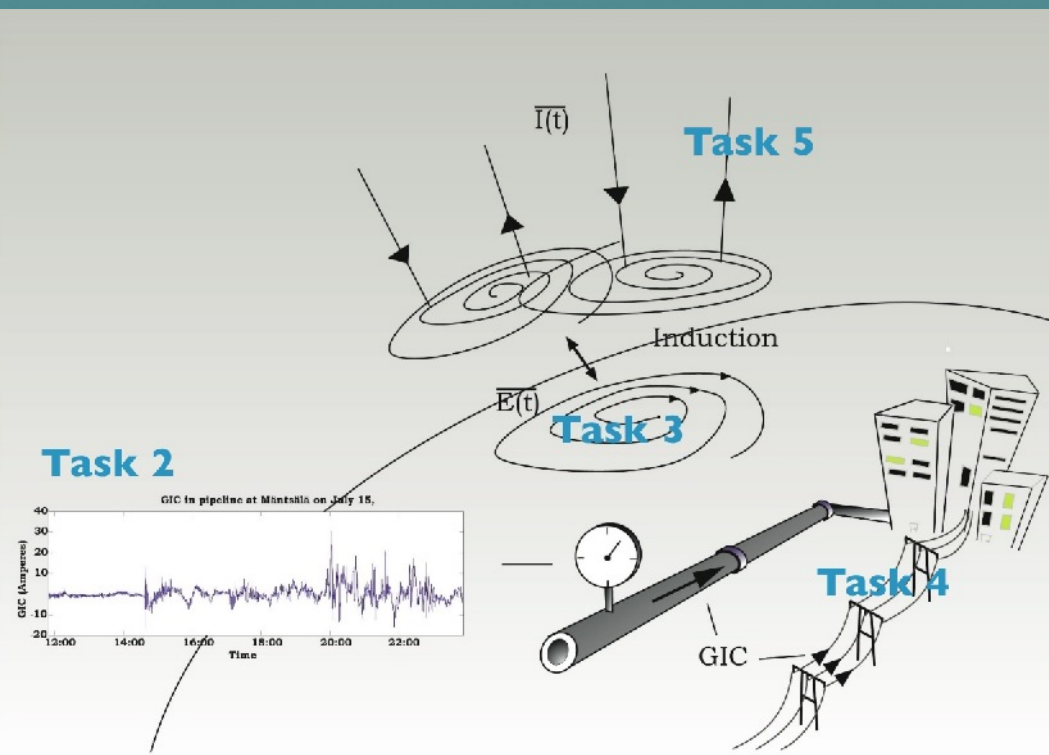
- GIC risk assessment in national high voltage power network
- Geoelectric field charts
- Crustal electrical resistivity maps



Correntes induzidas pelo campo geomagnético no território português (PTDC/CTA-GEO/31744/2017)

Domains: Valorização de Recursos Endógenos Naturais; Tecnologias para a Qualidade de Vida; Inovação Territorial; Mobilidade e Transportes - Tecnologias

The MAG-GIC project



T3: crustal electrical conductivity model (F. Santos)

T4: GIC modeling in power grid (F. Pinheiro & J. Ribeiro)

T2: Separation of GIC inducing sources (A. Morozova)

T5: Modeling of ionospheric equivalent sources (A. Pais)

T1: Relocation of COI geomag. station (P. Ribeiro)

Extra: Hall effect sensor for GIC measurements (J. Cardoso)

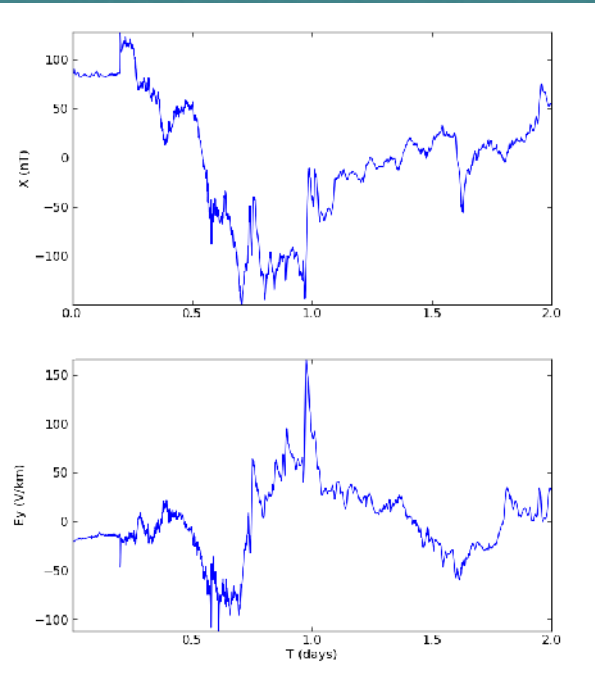
Consultants:

REN, M. Torta (Obs Ebro),
J. Cruz (IPMA), M. Mandaia
(IAGA), V. Lesur (IPGP)

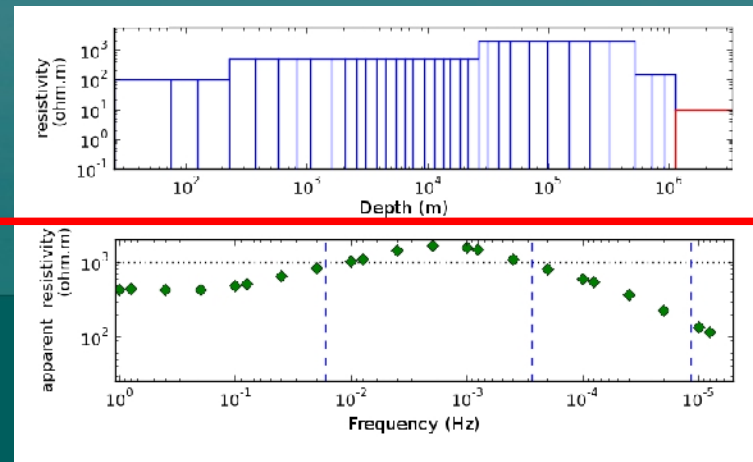
GLC inducing geoelectric fields

$$E_{x,y}(\omega) = 1/\mu_0 Z_{x,y}(\omega) \times B_{x,y}(\omega)$$

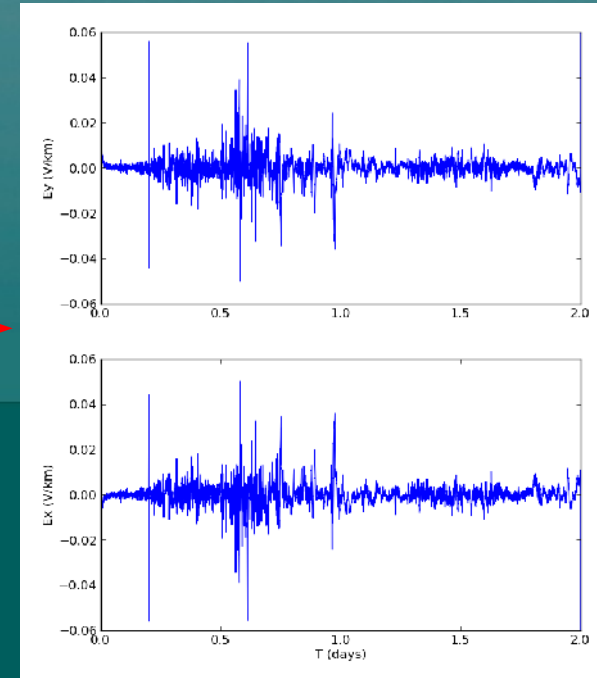
(Pirjola 2002)



COI geomagnetic
observations



Resistivity model
(e.g. Campbell 1998)

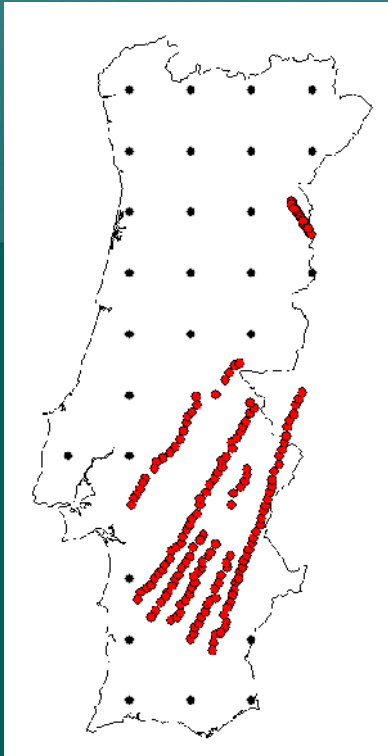


Estimated
induced field

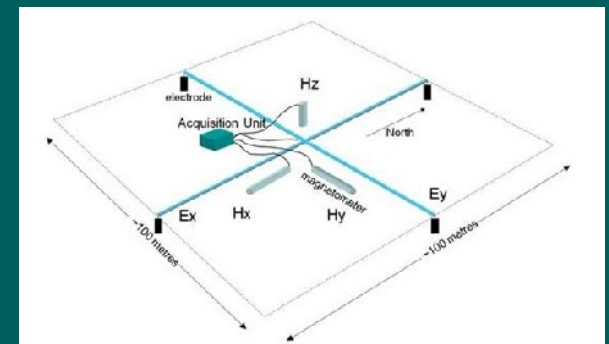
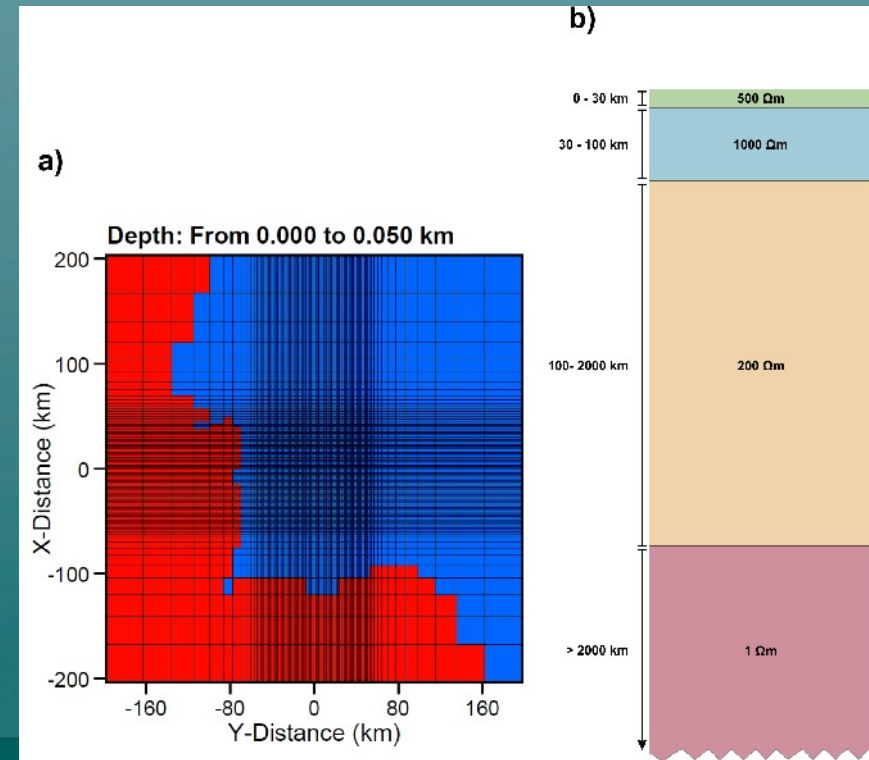
$$\text{Total current driver} = \int E \, dl$$

Crustal resistivity model

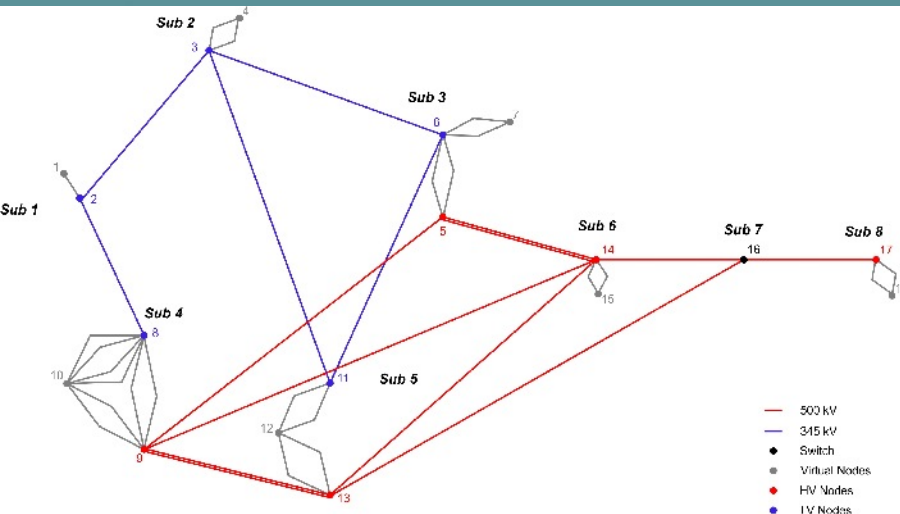
**Simplified 3D model:
Bathymetry + crustal conductivity
(Santos et al. 2003)**



**Final model:
Crustal conductivity
MT measurements
across the country**

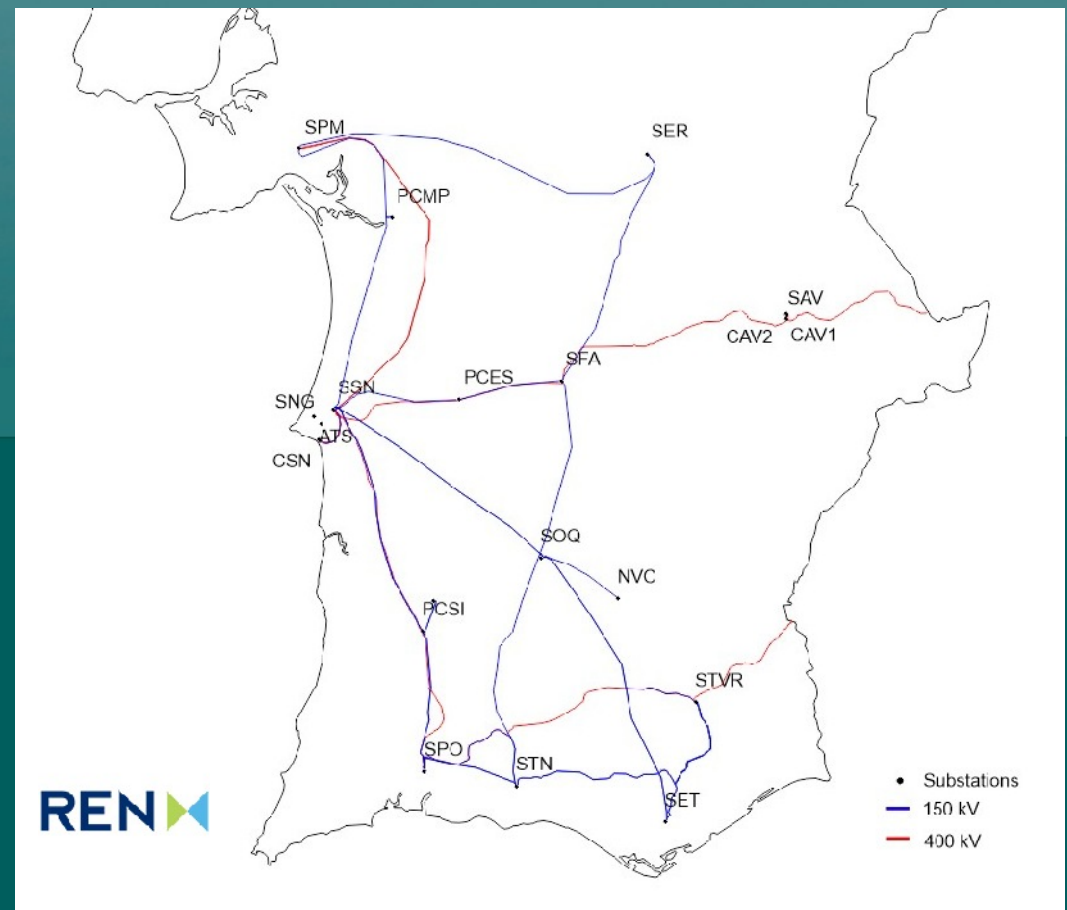


Power network model



Initial test:
Horton benchmark

Current stage:
Southern Portuguese
power network model



Following stage: entire Portuguese HV power network

GIC calculations

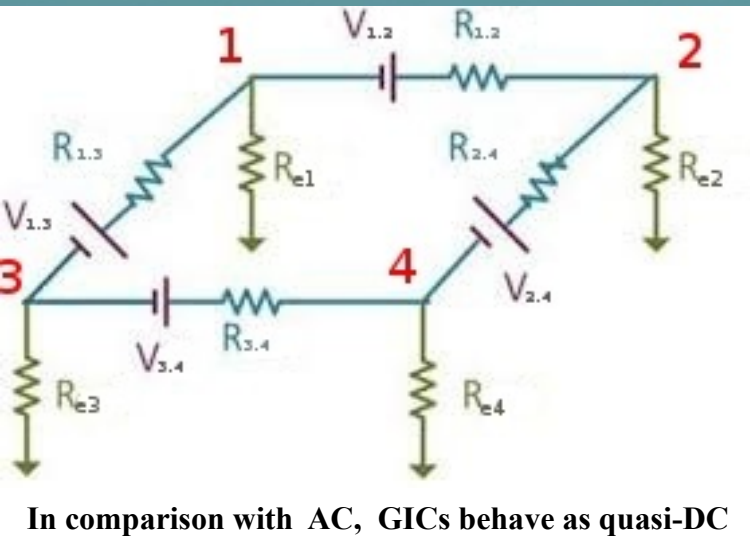
Lehtinen & Pirjola (1985)

$$I = (U + YZ)^{-1} J$$

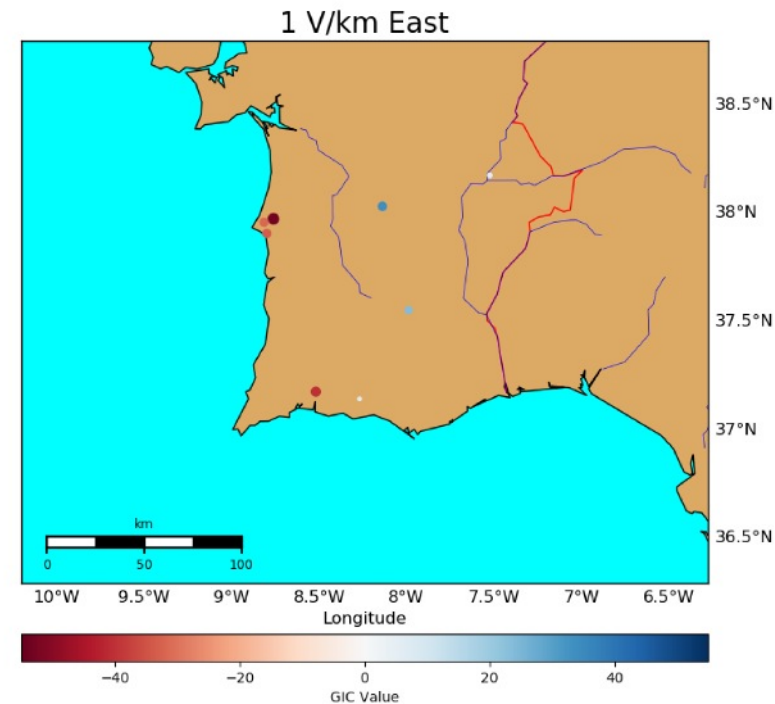
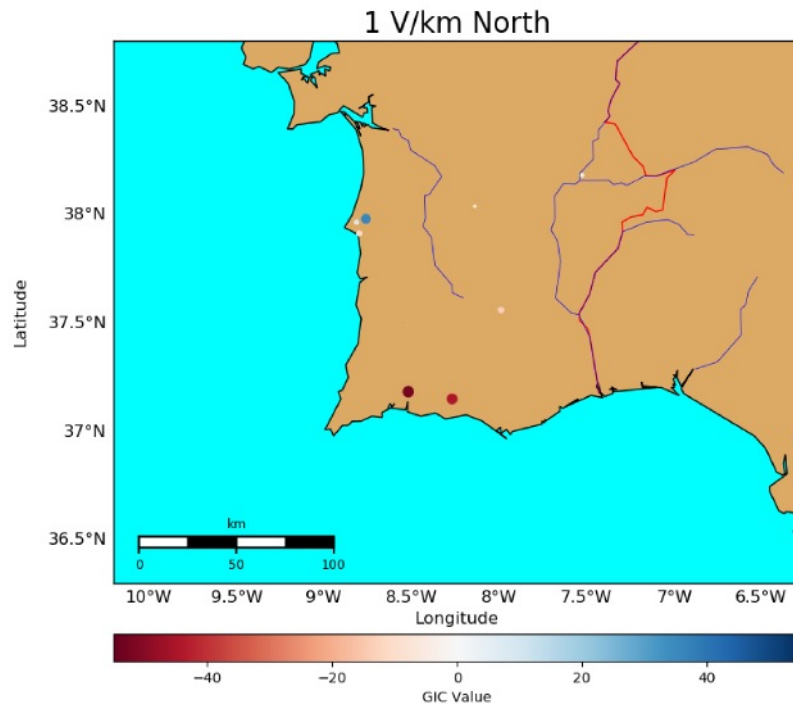
Network admittances

Grounding impedances

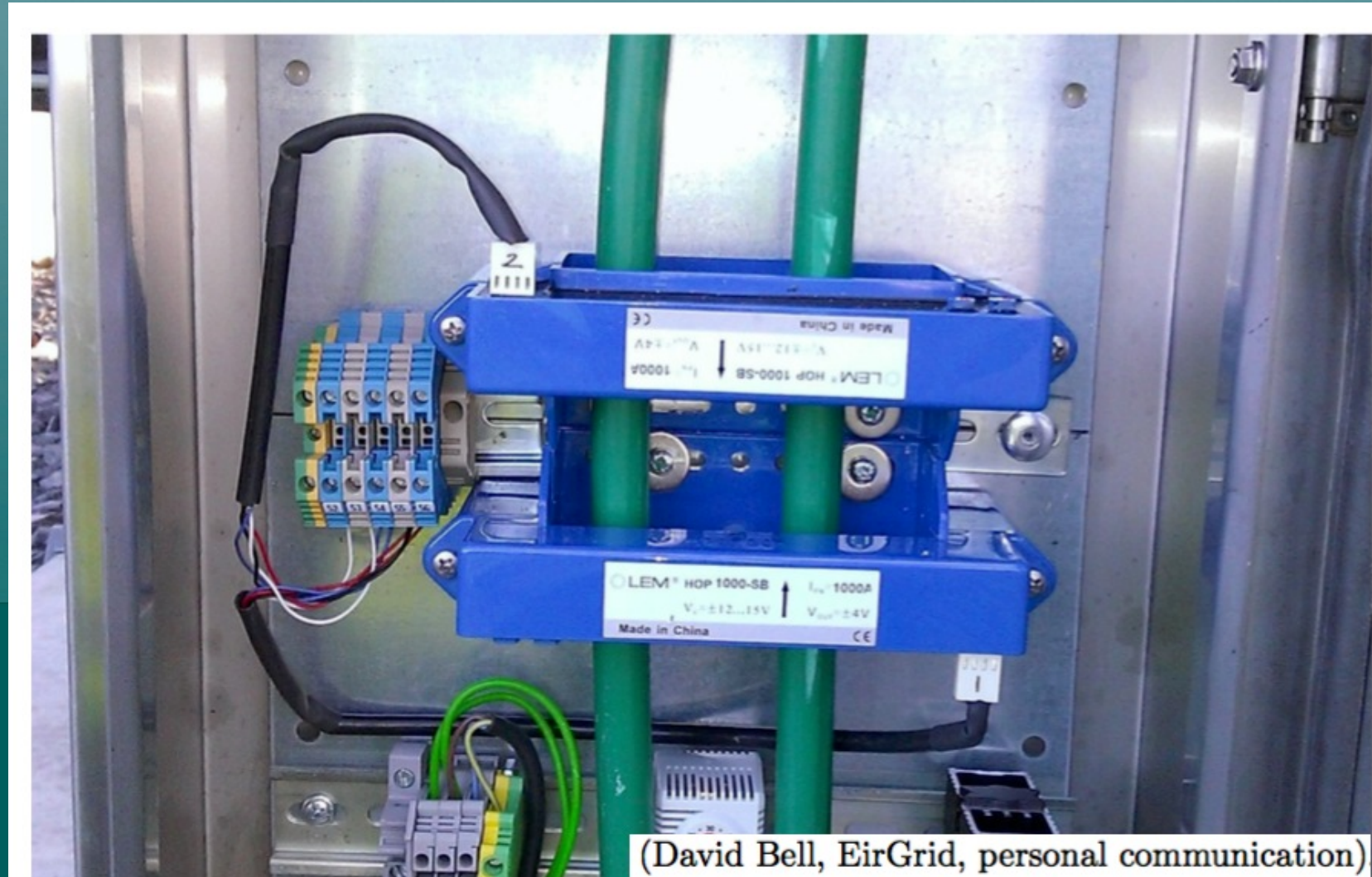
Network currents



In comparison with AC, GICs behave as quasi-DC



Hall effect sensor



Model validation & GIC monitorisation through the installation of a Hall effect sensor in a transformer station

Other uses for this know-how

- Improvements to the resistivity model
- Updating the power network model
- Other countries
- Other fields:

- Insurance

LLOYD'S

(report on losses from a Carrington type event)

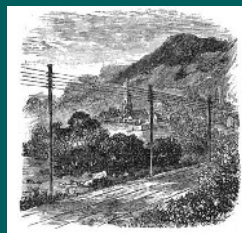
- Civil defense



- Pipelines



- Telegraph



(well, not really in use nowadays...)