The Impact of Space Weather on UK Railways

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Introduction

Geomagnetically induced currents (GICs) arising from space weather can adversely impact many ground-based systems, including railways

- Track circuit failures
- Damage to locomotive on-board transformers
- Possible injury to railway maintenance crew

Project Goal

To investigate the impacts of space weather on the UK railways using:

- Geomagnetic field interpolation methods
- Conductivity models of the UK
- Geoelectric field calculations
- Track circuit modelling

Background

Track Circuit Principles

- Insulating rail joints separate railways into blocks
- Track circuits detect current changes in their blocks
- GICs can "confuse" these relays, leading to false signals
- Using values for the geoelectric field, the extent to which track circuits are affected can be determined
- Magnetic field measurements are sparse, so an interpolation method is needed to compensate

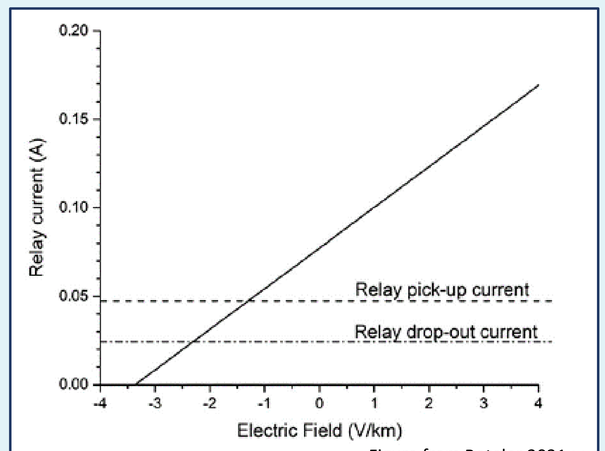


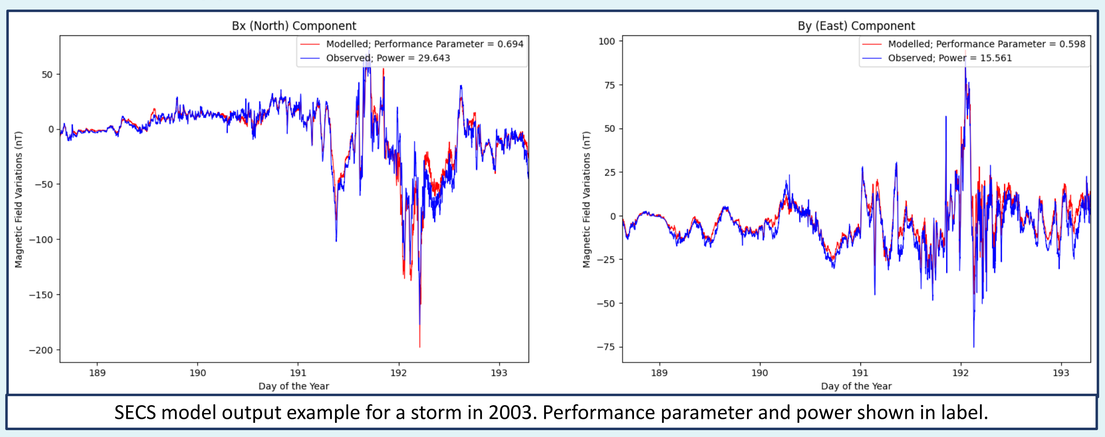
Figure from Boteler 2021 [1]

Dependence of the track circuit relay current on the geoelectric field. With no train present.

Method

Spherical Element Current System (SECS) Method [3][4]

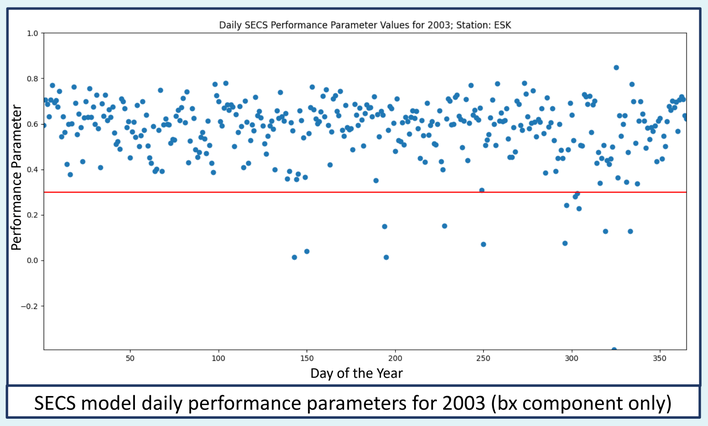
- Simulates ionospheric and magnetospheric currents
- Generated using magnetometer data from surrounding stations
- Magnetic field variations can then be interpolated at desired locations
- Performance parameter (P) to measure accuracy of model, where models that perform better have higher values of P, to a maximum value of 1 [2]



SECS model output example for a storm in 2003. Performance parameter and power shown in label.

Daily P Values

- For each day in 2003, the SECS model was run and the daily performance parameters were collated
- Set acceptance threshold of 0.3



SECS model daily performance parameters for 2003 (bx component only)

(Image from Interrail.eu)

Results

- Daily performance parameters for 2003 show that the model fell within acceptable limits 96% of days
- SECS model does not perform at acceptable limits when features such as the current wedge lie over the centre of the interpolation area – this effect will be somewhat negated when the station removed to verify the model is included within the model

Conclusions

The SECS model implemented:

- Is suitable to use for interpolating magnetic field values at track-side locations
- Performs at an acceptable standard on most quiet and stormy days
- Can provide poor result in the presence of a substorm current wedge over the interpolation area

Further Work

- Improvements to the SECS model – tweaks to model parameters
- Geoelectric field calculations – using ground conductivity models and magnetic field variations to estimate the geoelectric field at desired areas
- Model sections of UK railway network
- Analysis of recorded track-side measurements – currently postponed due to Covid-19

References & Acknowledgements

[1] Boteler, D. H. (2021). Modeling geomagnetic interference on railway signaling track circuits. Space Weather, 19, e2020SW002609. https://doi.org/10.1029/2020SW002609.
[2] Torta et al.: Assessing the hazard from geomagnetically induced currents to the entire high-voltage power network in Spain. Earth, Planets and Space 2014 66:87.
[3] Amm, O.: Ionospheric elementary current systems in spherical coordinates and their application, J. Geomag. Geoelectr., 49, 947–955, 1997.
[4] Amm, O. and Viljanen, A.: Ionospheric disturbance magnetic field continuation from the ground to the ionosphere using spherical elementary current systems, Earth Planets Space, 51, 431–440, 1999.

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