# Space Weather and UK Geomagnetically Induced Currents

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**Geomagnetically Induced Currents (GIC), which can flow in technological systems such as power transmission grids, are a consequence of the geoelectric field induced at the surface of the Earth during geomagnetic storms. This poster describes the development of a 3D 'Thin-Sheet' geoelectric field model which covers the whole of the UK and includes the influence of the surrounding shelf seas. The model can be used to compute the response of the geoelectric field to geomagnetic storms.**

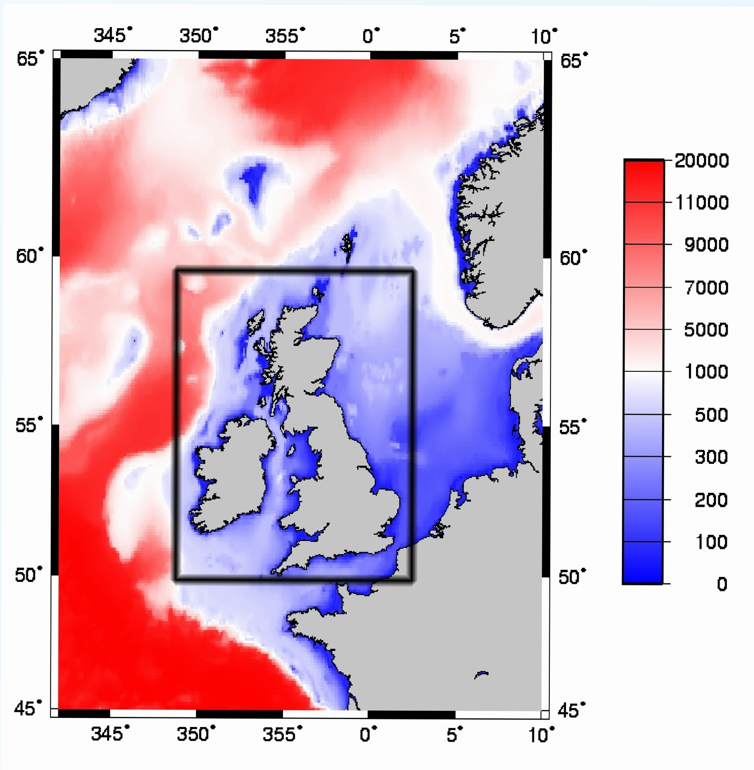
**In conjunction with a power grid model the geoelectric field model enables us to estimate GIC flows in UK power networks.**

**The geoelectric field and power grid models together form one component of a near real time GIC warning package that is currently being developed by BGS in conjunction with Scottish Power plc. This is known as 'SWIMIC' (Solar Wind monitoring and Induction Modeling for Induced Currents). The package is illustrated here, using examples of model outputs obtained during the October 2003 severe geomagnetic storm and taken from the project web site.**

## Electric Field Model Construction

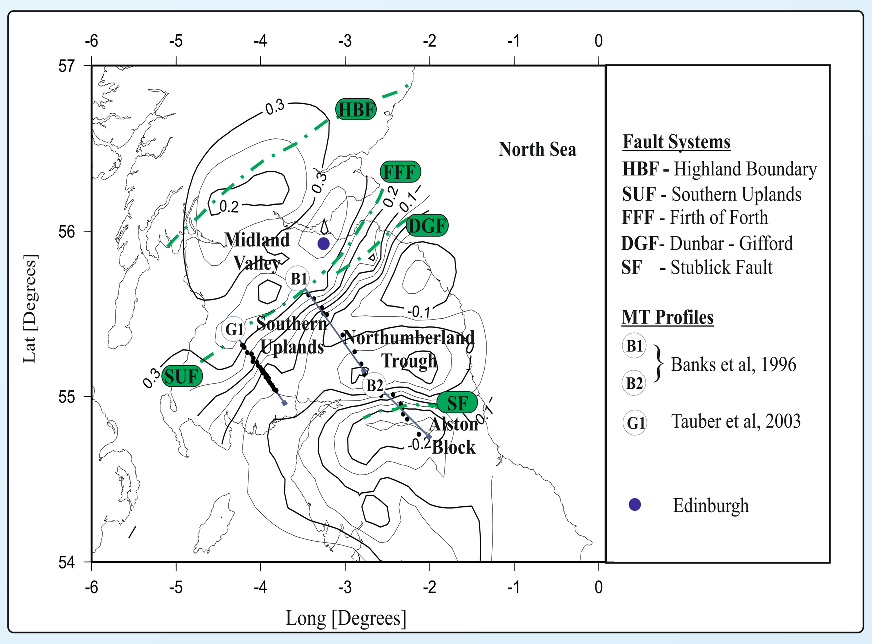
The typical variation period of GIC is from 10-1000s. Thus, the depth of penetration of electromagnetic fields in the Earth can be greater than 100km. Therefore, it is the gross geological structure underlying the UK which controls the overall response of the geoelectric field. However, the near surface (crustal scale) structure distorts the underlying response. We therefore employ a thin sheet modelling approach [1].

The model comprises a non-uniform thin sheet of laterally variable conductance (depth integrated conductivity) at the surface of a layered half-space. We use ETOPO5 bathymetry data, the spatial variation of observed magnetic fields and previous electromagnetic modelling [2,3] to control the distribution of conductance in the surface sheet.



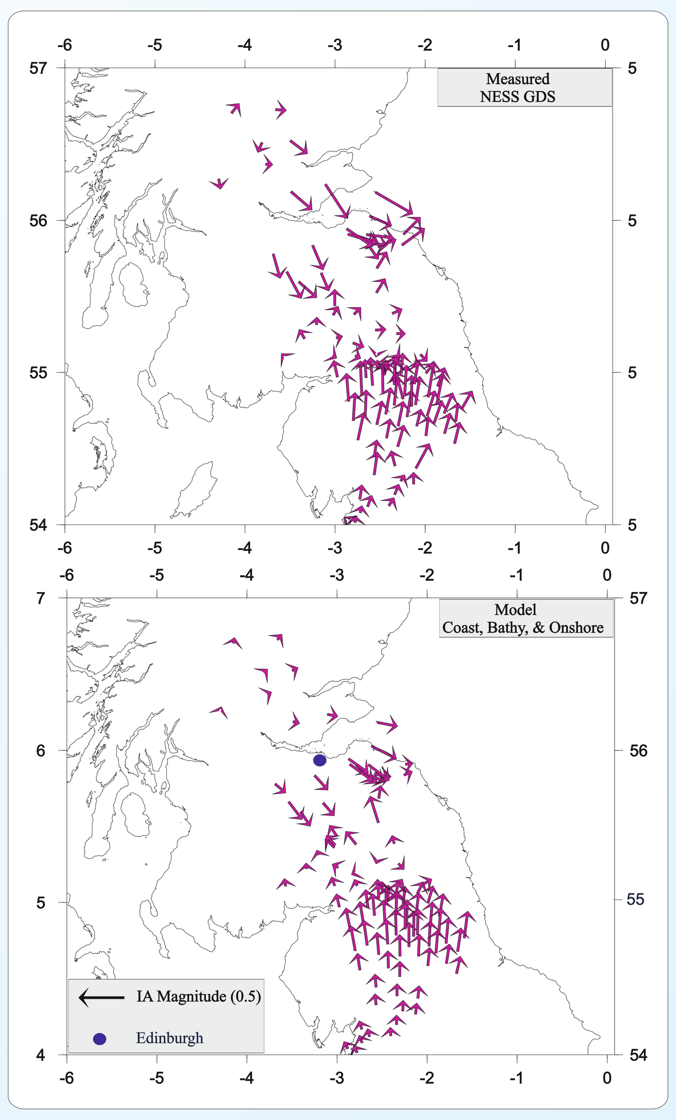

*Above:* Calculated conductance (S) of the surrounding shelf seas using ETOPO5 Bathymetry data.

*Below:* Hypothetical event map [e.g. 4] of the observed anomalous vertical magnetic fields (nT) in Southern Scotland and Northen England when the reference magnetic field is 1nT and polarised north. Large spatial gradients of the vertical field indicates the presence of a conductivity boundary. This highlights the two main geological anomalies of the area which are likely to influence GIC in the Scottish Power grid: the Southern Uplands Fault and Northumberland Basin.



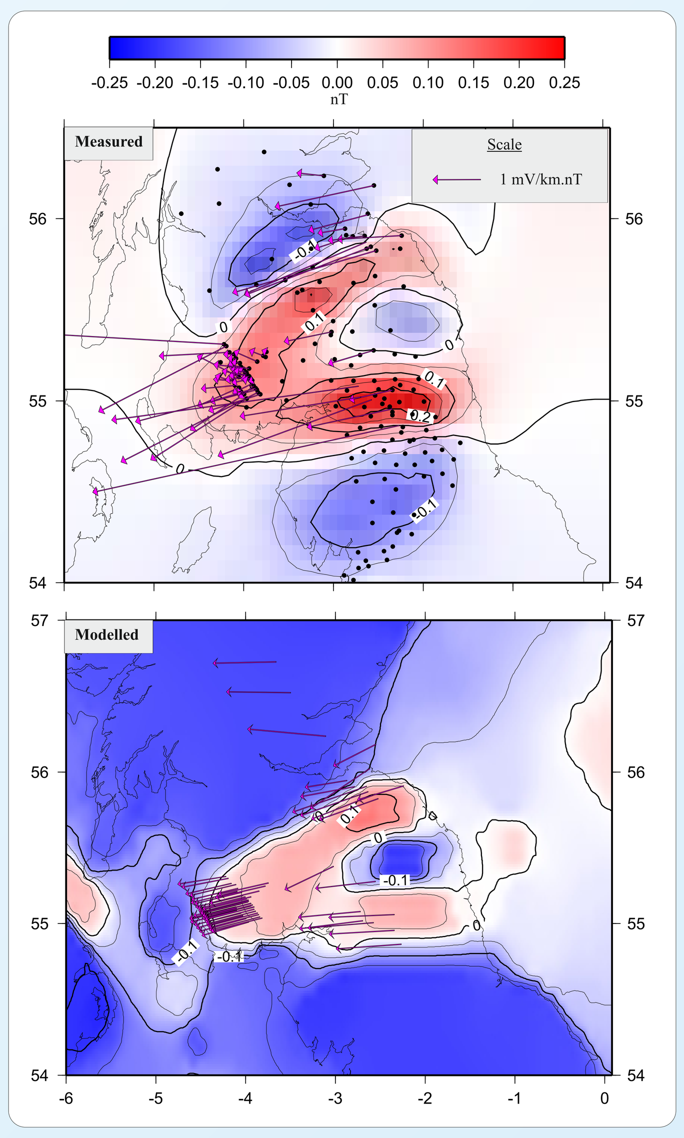

## Model E-Fields and Measured Data

We have compared the model to Southern Scotland and Northern England electromagnetic induction data collected from numerous field campaigns [5, and references therein]. These data are estimates of vertical magnetic field and telluric response functions. Tensor decomposition was used to correct the telluric response functions for the effect of static shift on the azimuth of the electric field [6].



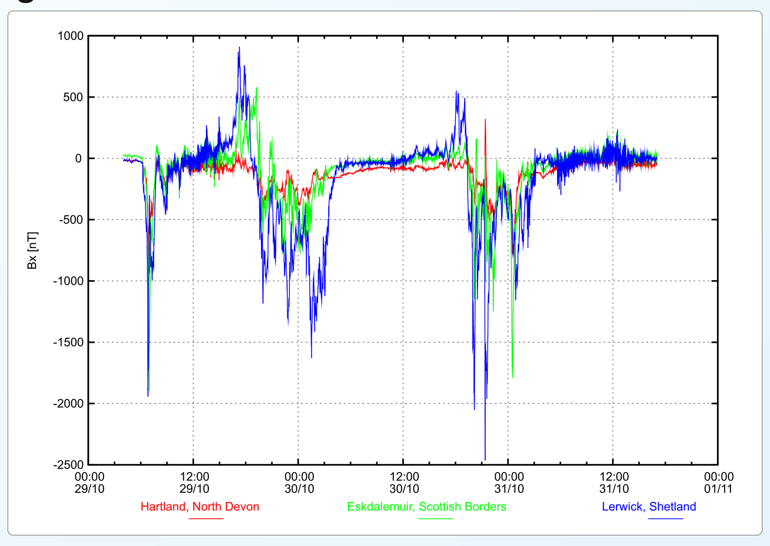

Above: Measured and modelled induction arrows in the Central Scotland and Northern England Region. The Parkinson convention is employed. Thus, the arrows point towards regions of higher conductance.

*Below:* Measured and modelled electric field vectors and the anomalous horizontal X (North) component of the magnetic field when the reference magnetic field is 1nT and polarised 0°N. The black dots are magnetic field measurement sites [see 6].

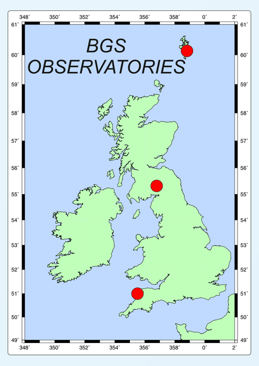



## The 'SWIMIC' Package (1)

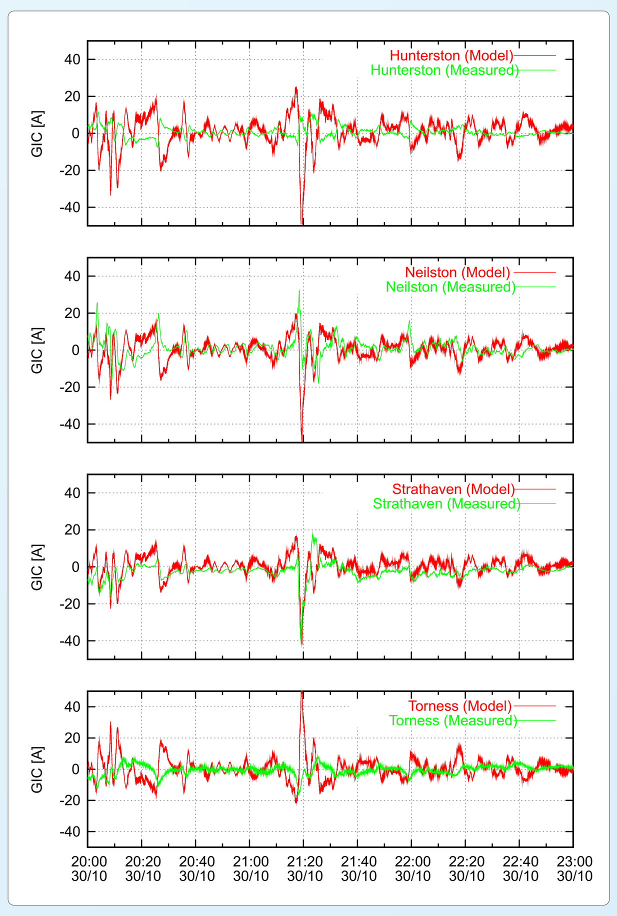
Models of the electric field, and BGS measurements of the magnetic field, enable us to calculate GIC throughout the Scottish Power grid. As part of the European Space Agency 'pilot projects' we have developed a model of the Scottish Power grid. This provides an estimate of GIC throughout the power grid in near real time, currently based on a 1D model of the surface electric field. Comparisons with measured data (below) highlight the fact that more work is required. Future work will update the model of the power grid and include a non-uniform geoelectric field model.

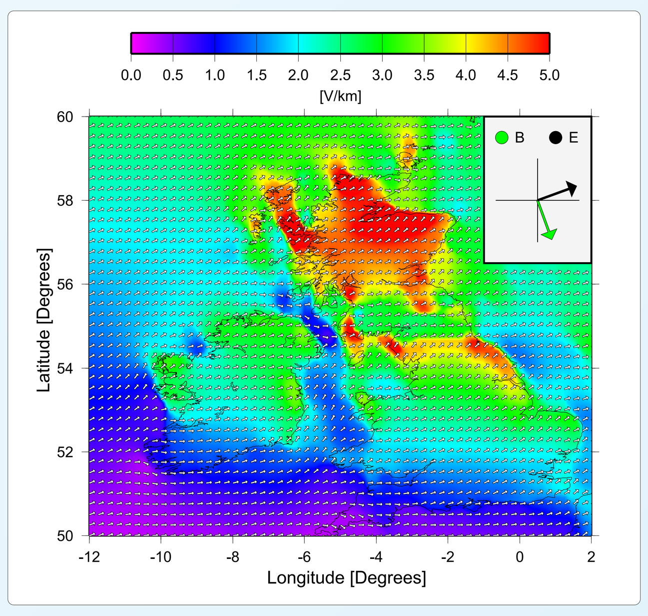


*Above:* X (North) component of the geomagnetic field at each of the BGS observatories during the 30th October geomagnetic storm. *Right:* The three UK BGS Observatories.



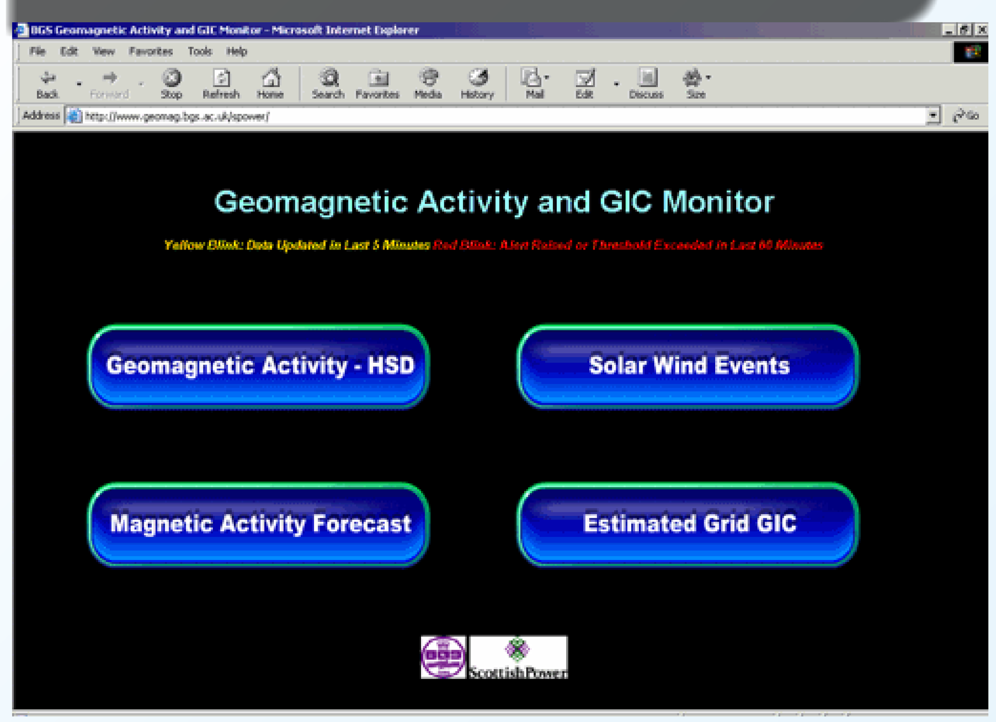

*Below:* Modelled and measured GIC at each of the four Scottish Power monitoring sites during the 30th October 2003 magnetic storm. A 1D model of the Earth was employed to calculate the geoelectric field from BGS magnetic observatory. At one site (Strathaven) the model and measured GIC compare favorably, while at other sites the fit is less good. Work is in progress to include the 3D thin-sheet modelling, and update the grid model.

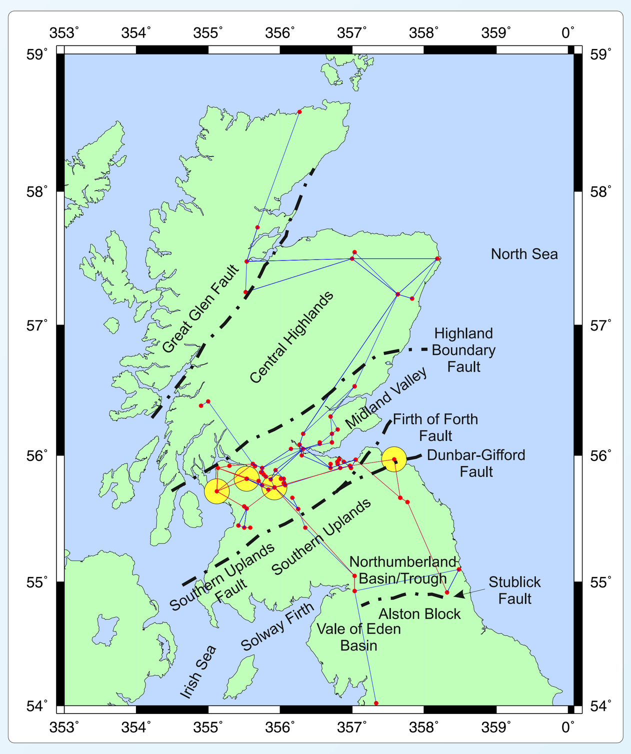


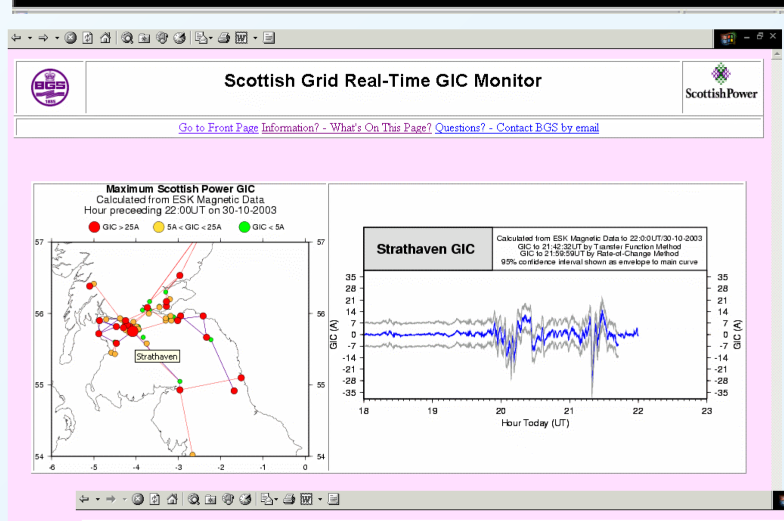




*Left:* An estimate of the geoelectric field at the peak of the 30th October 2003 storm (approx 21:20UT). The inset shows the direction of the surface electric field for a one-dimensional electrical model of the crust. The main map shows local variations due to the three-dimensional model employed.

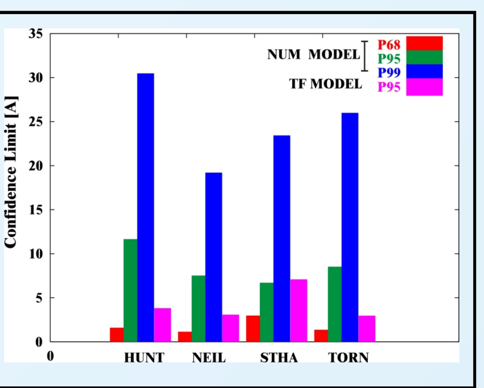
## The 'SWIMIC' Package (2)



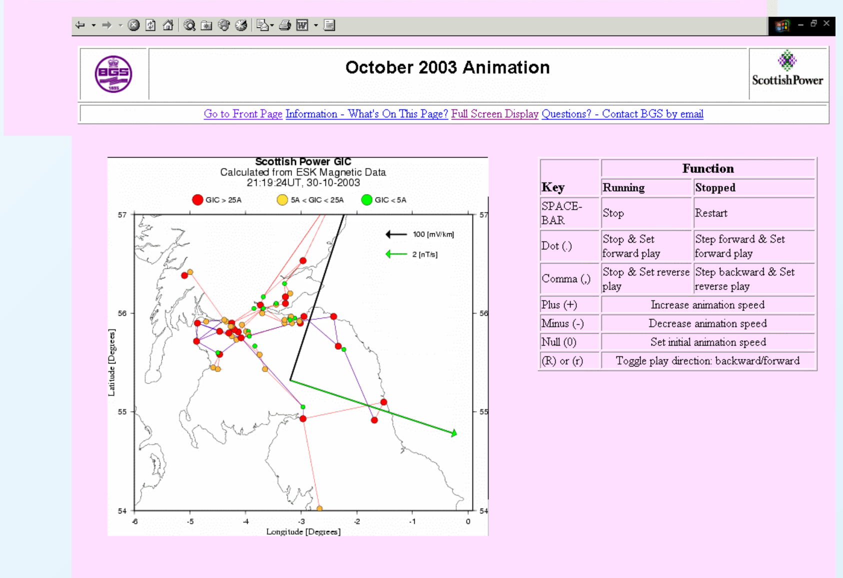




| | $P_{68}$ [A] | $P_{95}$ [A] | $P_{99}$ [A] | $P_{95}$ (TF) [A] |
|---|---|---|---|---|
| HUNT | 1.6 | 11.7 | 30.5 | 3.8 |
| NEIL | 1.1 | 7.5 | 19.2 | 3.1 |
| STHA | 3.0 | 6.7 | 23.4 | 7.1 |
| TORN | 1.4 | 8.5 | 26.0 | 3.0 |




For GIC calculated throughout the network: assume these four sites are 'representative' and calculate an average error ($P_{95}$) of +/- 8.6A




Top Left: Web interface, *click 'Estimated Grid GIC' for*
Middle Left: Grid outputs, with one station highlighted
Lower Left: Interface to animation of last hour's GIC
Top Right: The Scottish Power grid in context
(GIC measurement stations highlighted in yellow)
Middle Right: GIC model accuracy at various percentiles, for network ('num') model and simpler site transfer function ('TF') models

*Yet To Be Completed*:

1. Alternative means of data delivery to Grid Control.
2. Update model to 2006 power grid.
3. Use 3D conductivity model for real time operation.
4. Predict GIC from solar wind data using neural nets.

Acknowledgements:
**Models:** BGS, FMI, Univ. Edinburgh
**Data:** Scottish Power, Univ. Edinburgh

ScottishPower

**References:**
[1] G. Vasseur and P. Weidelt, Geophys. J. R. astr. Soc., 51:669-690, 1977
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[6] J.T. Smith, Geophys. J. Int., 130:65-72, 1995