British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Past BGS activities assessing the geomagnetic hazard to the Scottish Power network and transformer infrastructure

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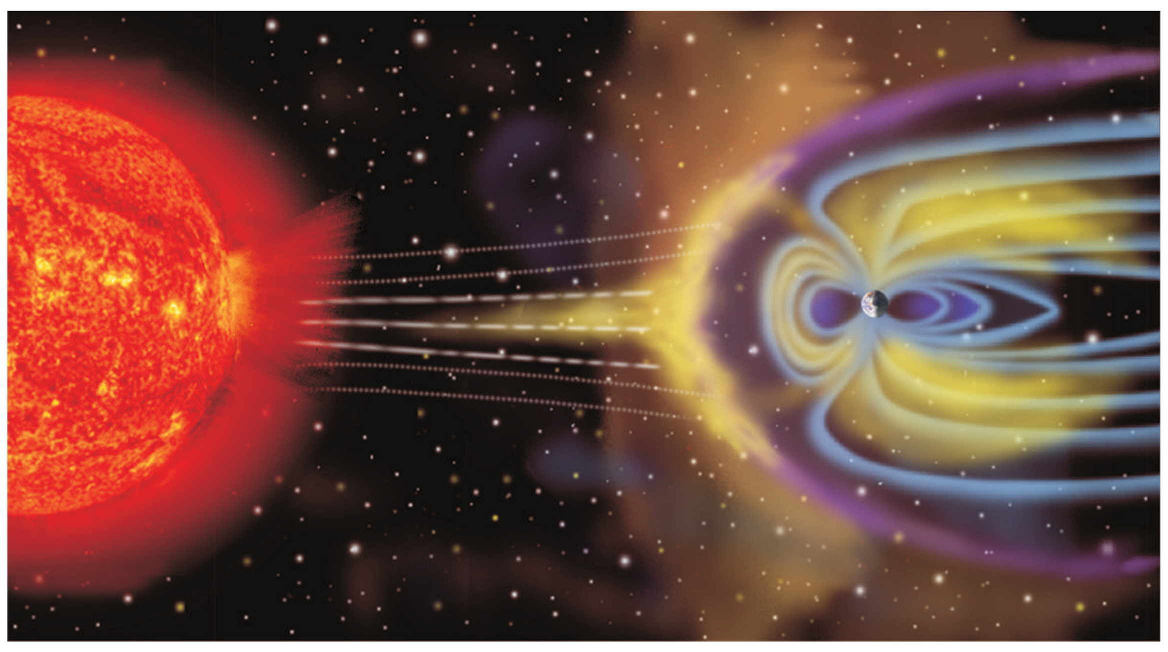
Introduction - Space Weather

“Space weather” describes the interaction between the Sun and the Earth’s magnetic field and its effect on technology. Variations in the Earth's magnetic field can pose certain risks to technological systems such as satellites and power grids. The loss of service or degradation to the operational life-span caused by geomagnetic events can have a financial cost to the operator; a severe geomagnetic disturbance could affect the general population through power outages or the loss of communication and navigation satellites that we have come to rely on.

The Sun radiates a solar wind – a stream of charged particles – that interacts with the Earth’s magnetic field. The Sun goes through an 11-year activity cycle and during active solar phases periodic and sporadic enhancements of the solar wind can result in magnetic storms on Earth.

Geomagnetic disturbances heat the atmosphere increasing drag on orbiting satellites. The rapidly time-varying geomagnetic field can affect navigation equipment sending underground well bores off-course. It can also induce currents in the ground which can overload and damage transformers in power grids.

The British Geological Survey (BGS) has expertise in providing advice or solutions to these problems to customers such as the European Space Agency, oil and gas exploration companies and local and national power grid operators.



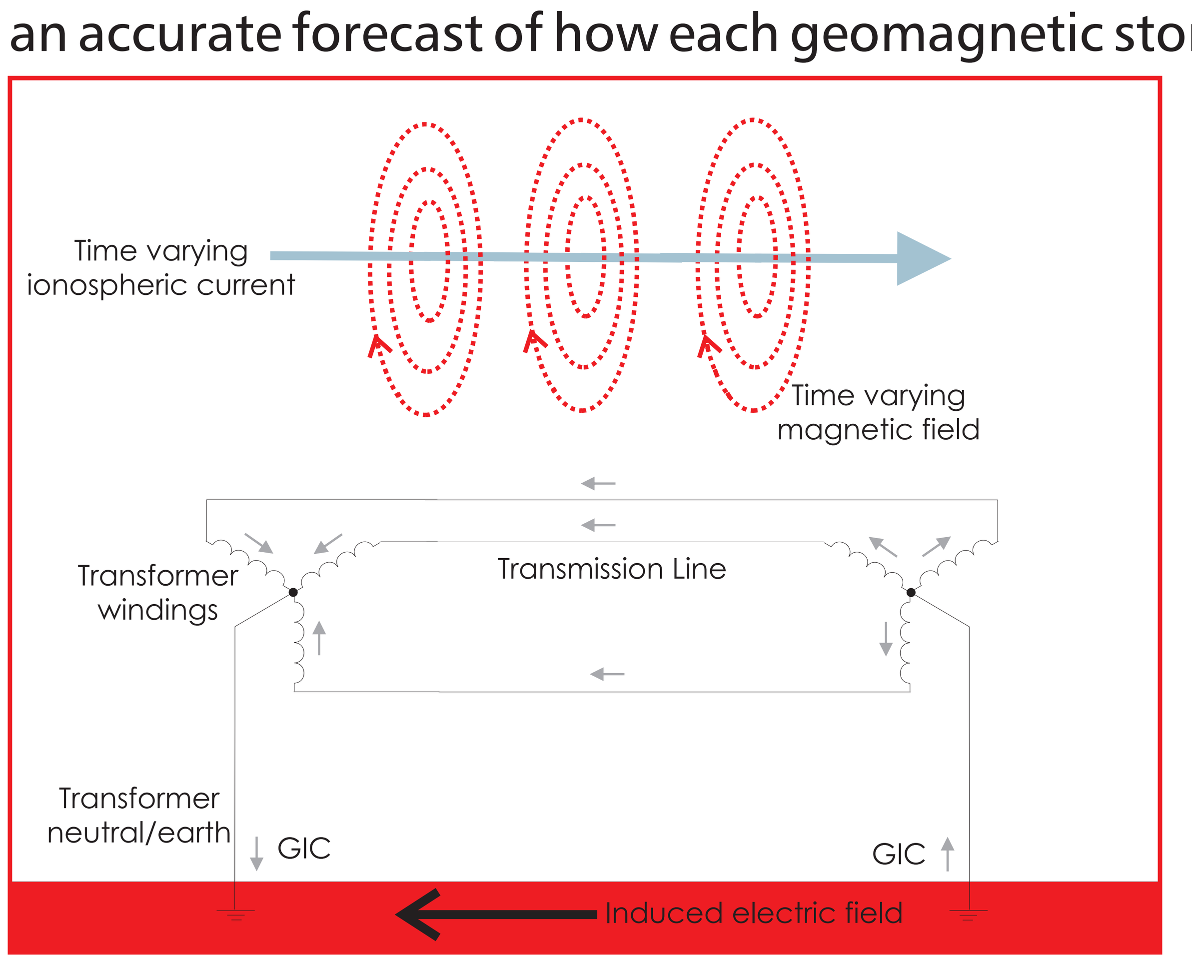
An artist’s impression of solar-terrestrial interactions. Image credit: NASA

Hazard - Geomagnetically Induced Currents

Geomagnetic storms cause electrical currents (*geomagnetically induced currents* or GIC) to flow in the Earth. Conducting networks with Earth connections, such as electrical power grids, can provide a 'short circuit' path for these GIC. GIC can cause a variety of problems including malfunction, damage, or premature ageing of power transmission equipment.

During the major geomagnetic storm of March 1989 the Canadian Hydro Québec power system failed as a result of GIC. The resultant nine-hour outage affected six million people with damage and losses estimated at hundreds of millions of dollars.

Operational mitigation is considered one of the best strategies to minimise the hazard posed by GIC. This requires prior warning, and, ideally, an accurate forecast of how each geomagnetic storm will develop.

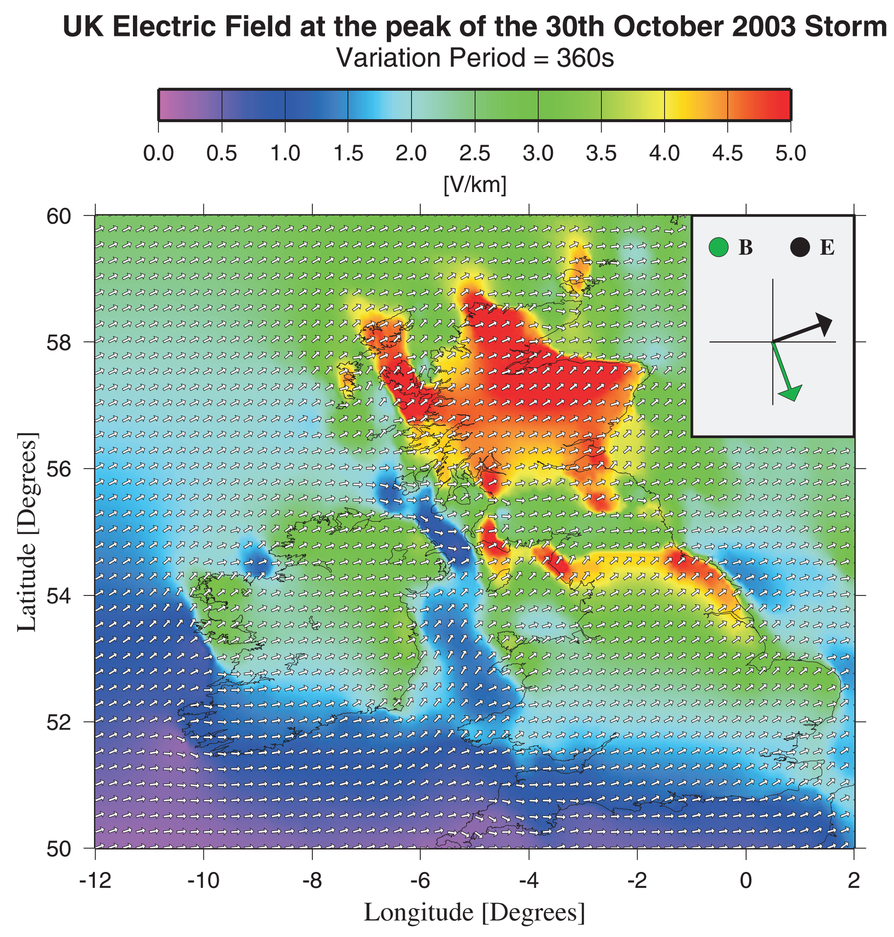


How GIC are formed. A time-varying current in the ionosphere induces a DC current in the ground that flows from Earth through transformers windings causing damage.

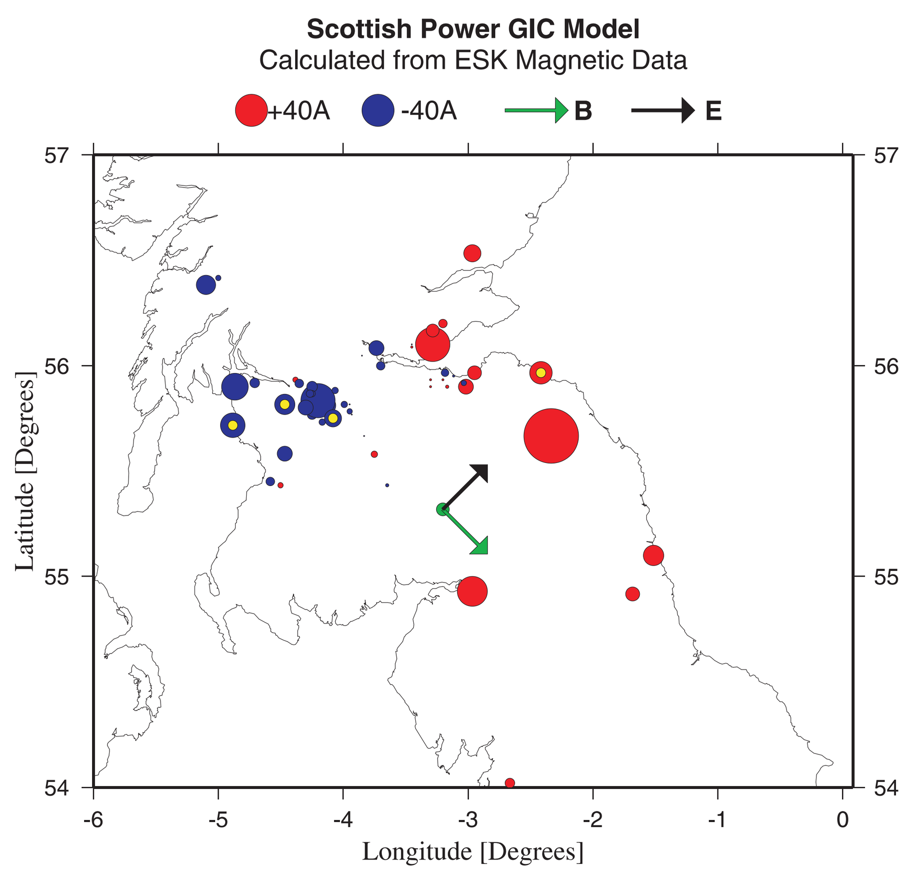
Mitigating Risk - BGS services to Scottish Power

Between 1999 and 2005 BGS provided a daily GIC monitoring and analysis service for Scottish Power (SP) grid control. This was intended to aid management of the GIC risk to assets in the Central Scotland power grid. A DC network model of the high voltage (275 and 400 kV) grid was developed along with a detailed 3D electrical conductivity model for the UK and its nearby continental shelf. Understanding the response of the electric field allowed for the identification of likely grid (transformer) risk points following major geomagnetic storms.

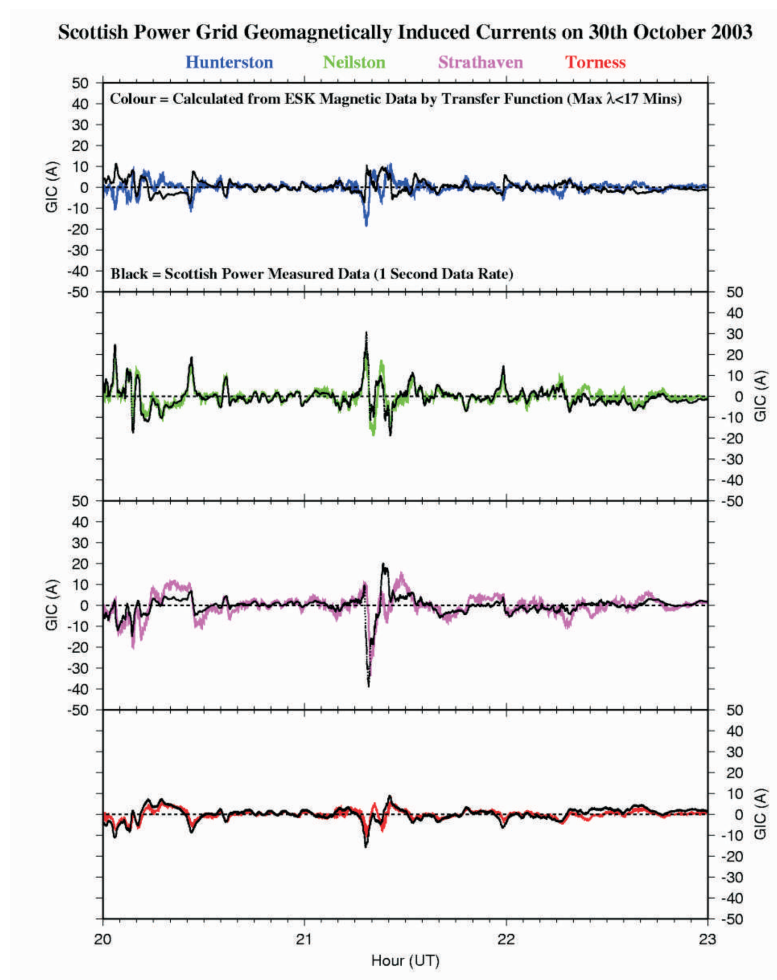
These model data were supplemented by measured GIC data at four key sites in the grid network (Hunterston, Neilston, Strathaven, and Torness). The model and measured data at the four points demonstrated a level of agreement that provided confidence in the model output throughout the grid. A daily geomagnetic forecast service of the likelihood of storm conditions in the following three days was also provided for SP.



Left: A model estimate of the geoelectric field across the UK during the six-minute peak in the 30th October 2003 magnetic storm. A strong enhancement of the electric field is evident during the disturbance: typical variations during a quiet geomagnetic day are expected to be less than 0.1V/km.



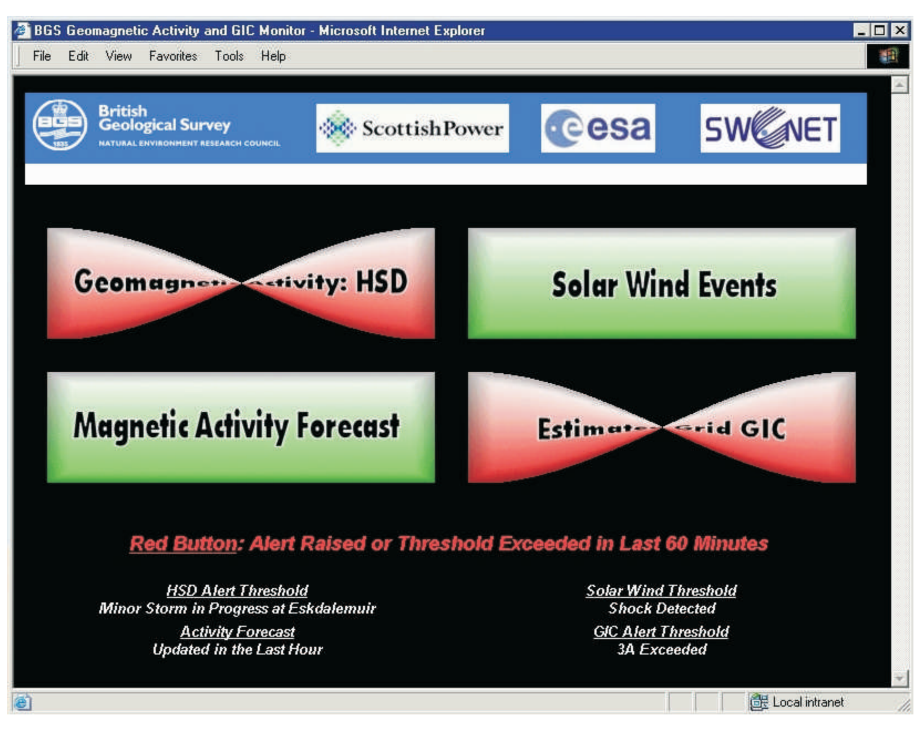
Bottom left: Calculated maximum GIC for the 30th Oct 2003 storm by combining the model of the electric field with measurements of the geomagnetic field. Yellow points mark the four permanent GIC monitoring stations.

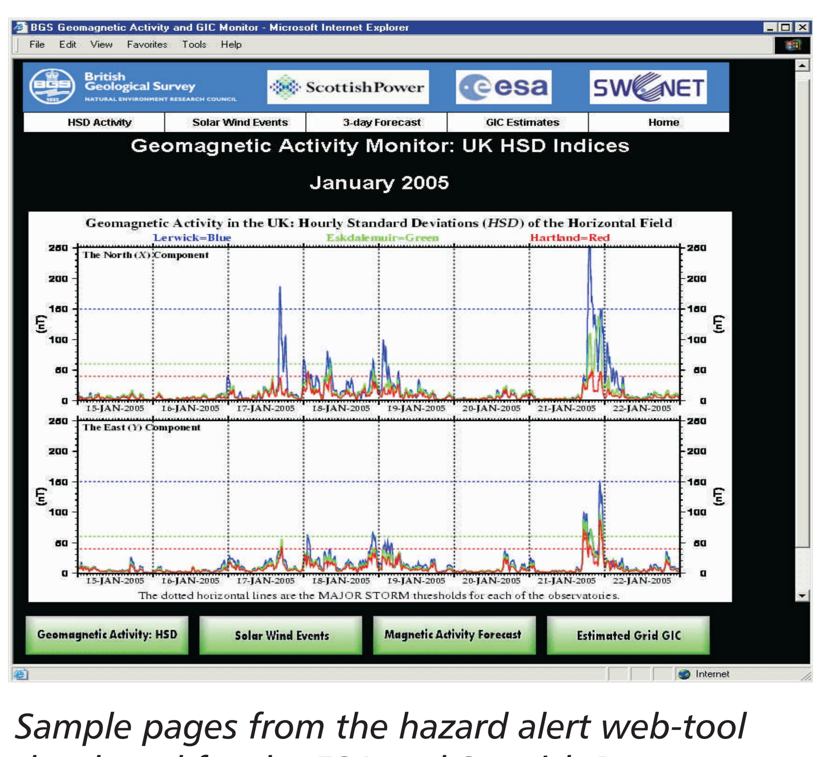


Below: How the modelled GIC compares with actual GIC recorded at the four GIC monitoring stations during the 30th October 2003 storm.

The annually renewed service was terminated following transfer of UK-wide grid management duties to the National Grid Company in 2005.

BGS subsequently developed a web tool to collate various in-house resources for the warning and analysis of GIC in the UK, with partial support from the European Space Agency. This was part of a European-wide program to assess the potential of general 'space weather' services. BGS remains involved in GIC scientific studies at a European level and continues to liaise with Scottish Power on potential areas of research.





Sample pages from the hazard alert web-tool developed for the ESA and Scottish Power.