British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Applied geoscience for our changing Earth

Modelling of Extreme Space Weather Events in the UK Power Grid

Alan WP Thomson, David Beamish, Ciaran Beggan, Gemma Kelly

Acknowledgements

Project *EURISGIC*:

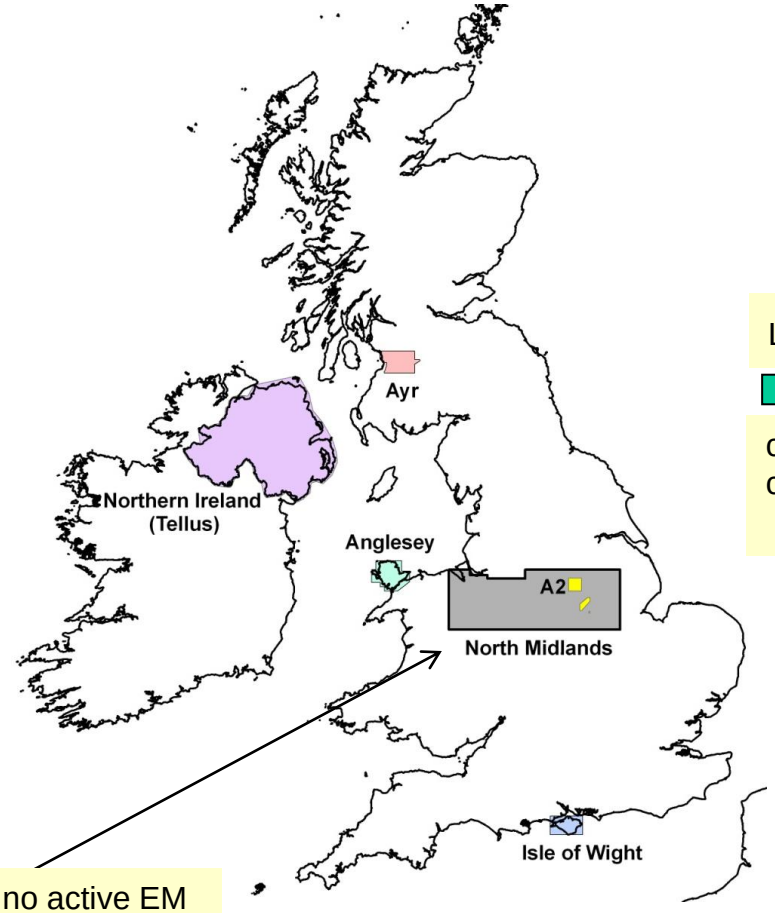
Ari Viljanen (FMI, FI), Peter Wintoft (IRF, SE), Magnus Wik (Neurospace, SE), Yahroslav Sakharov (PGI, RU), Viktor Wesztergom, (GGRI, HU), Antti Pulkkinen (CUoA, NASA Goddard)

Scottish Power (UK), National Grid (UK), EirGrid (IE)

Steps to a ‘Second Generation’ UK GIC Model

- New ‘geological conductivity’ model of top 3km of crust
- GB wide model of 400, 275 and 132 kV transmission system
- Geomagnetic variations interpolated across UK using ‘spherical elementary current systems’ method of Amm *et al*
- **Extreme event scenarios**
  - Royal Academy of Engineering report on space weather impacts on technology
- Geo-electric field measurements
  - E-field model validation
- Irish transmission system modelling
  - 1st steps, in association with EirGrid

UK airborne geophysical survey (fixed-wing) data has acquired high-resolution active frequency-domain EM and provided measurements of subsurface conductivity

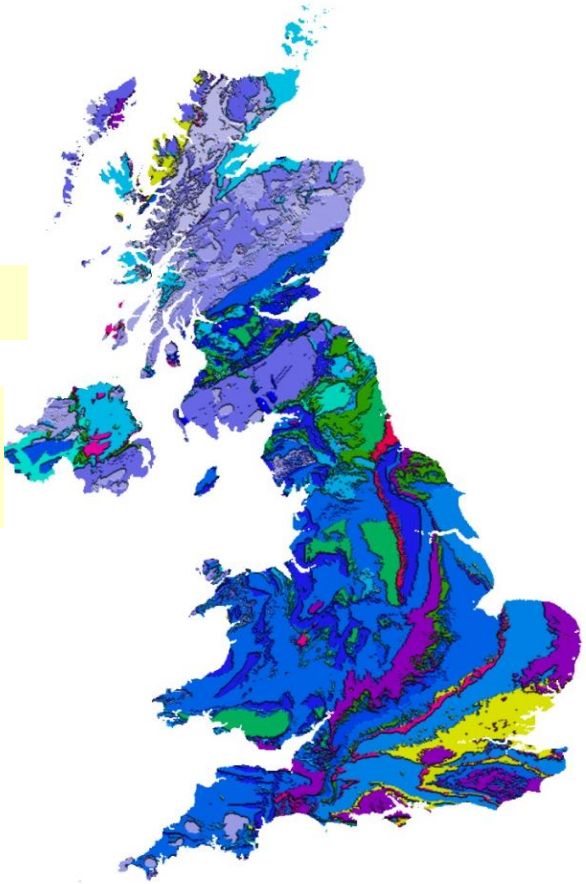


HiRES-1, no active EM

New bedrock conductivity map

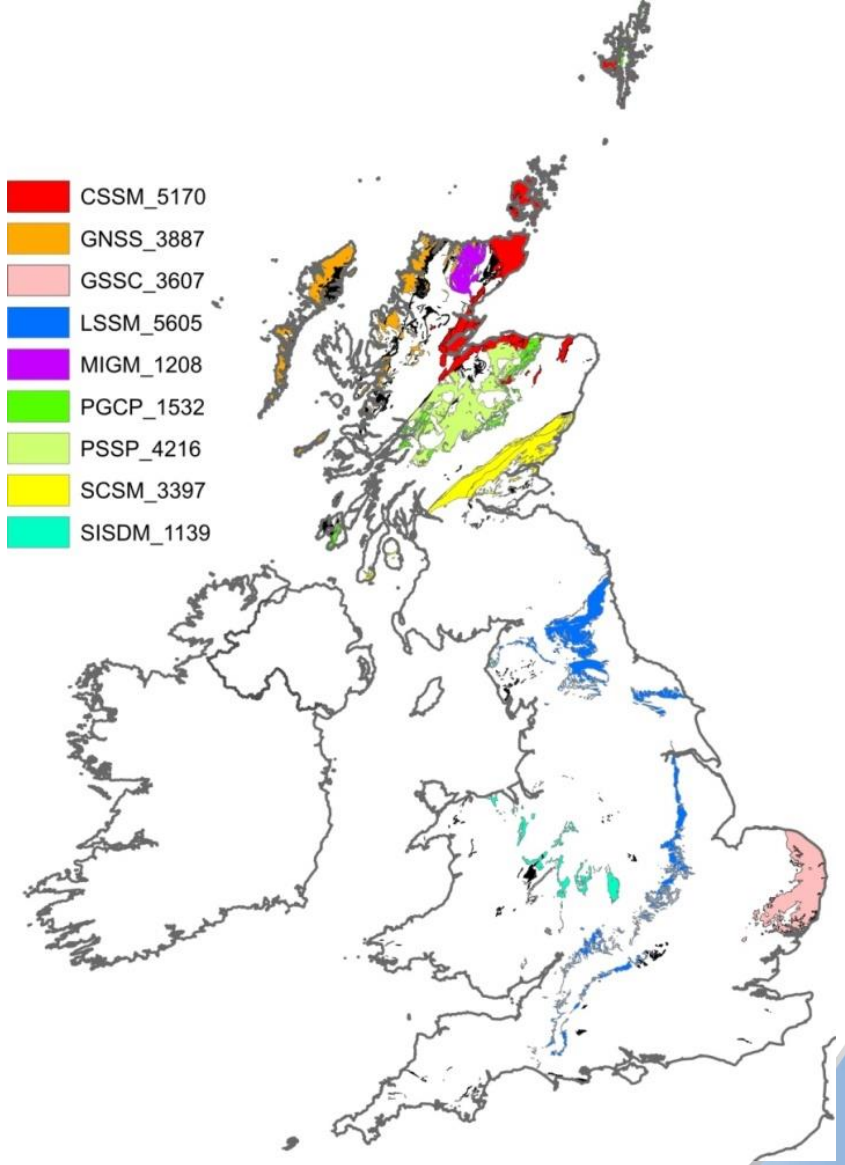
Lithological

classification of conductivity



86 units

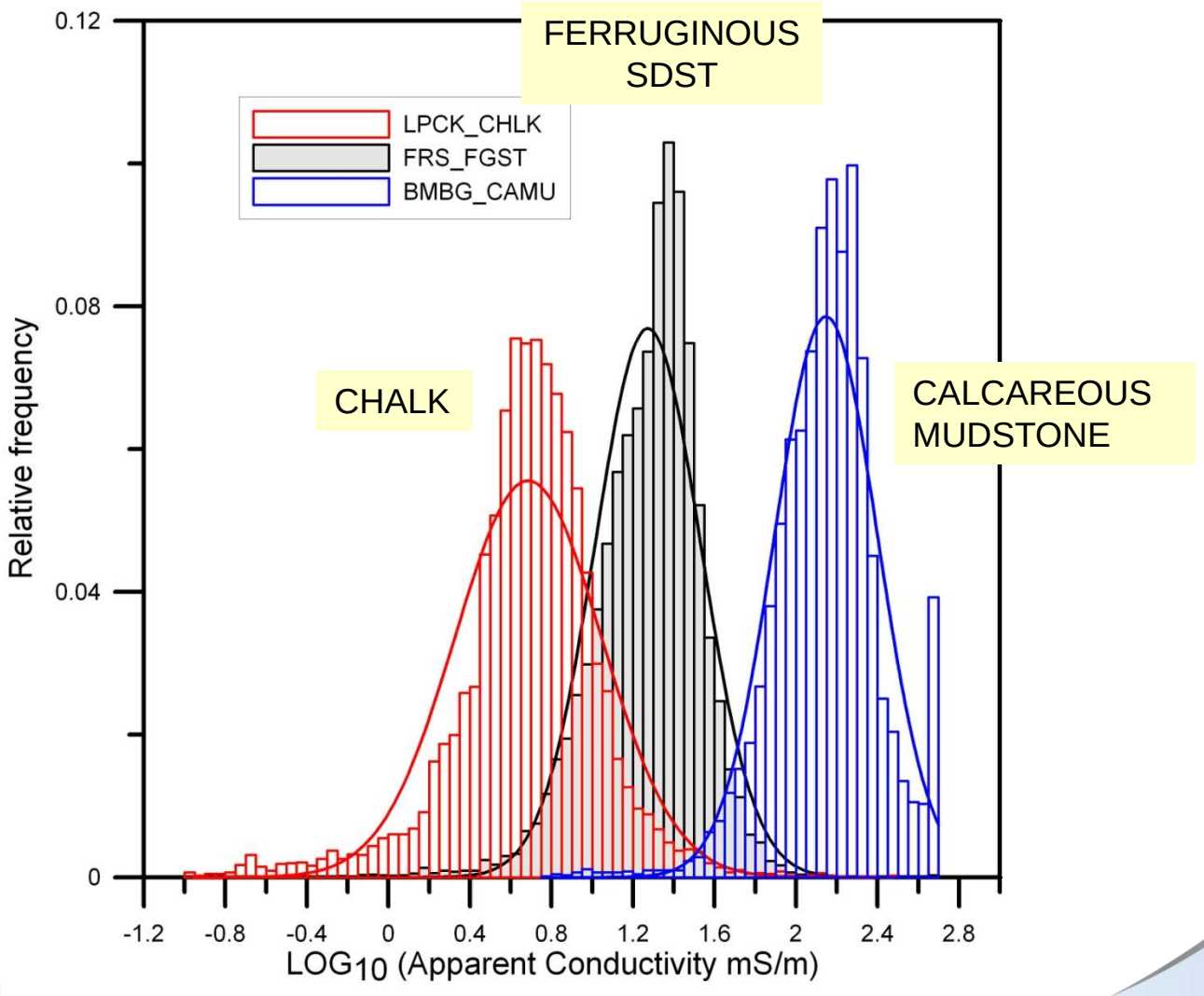
- AEM surveys covered 54 of the required 86 lithologies and provided 3 kHz conductivity estimates (best for bedrock)
- 32 missing, some very small areas
- The major 9 missing lithologies, are shown right
- Use natural lithological associations to provide conductivities for the missing 32



The distribution of the 32 unsampled lithologies.The 9 lithologies having total areas > 1000 km^2.shown in colour

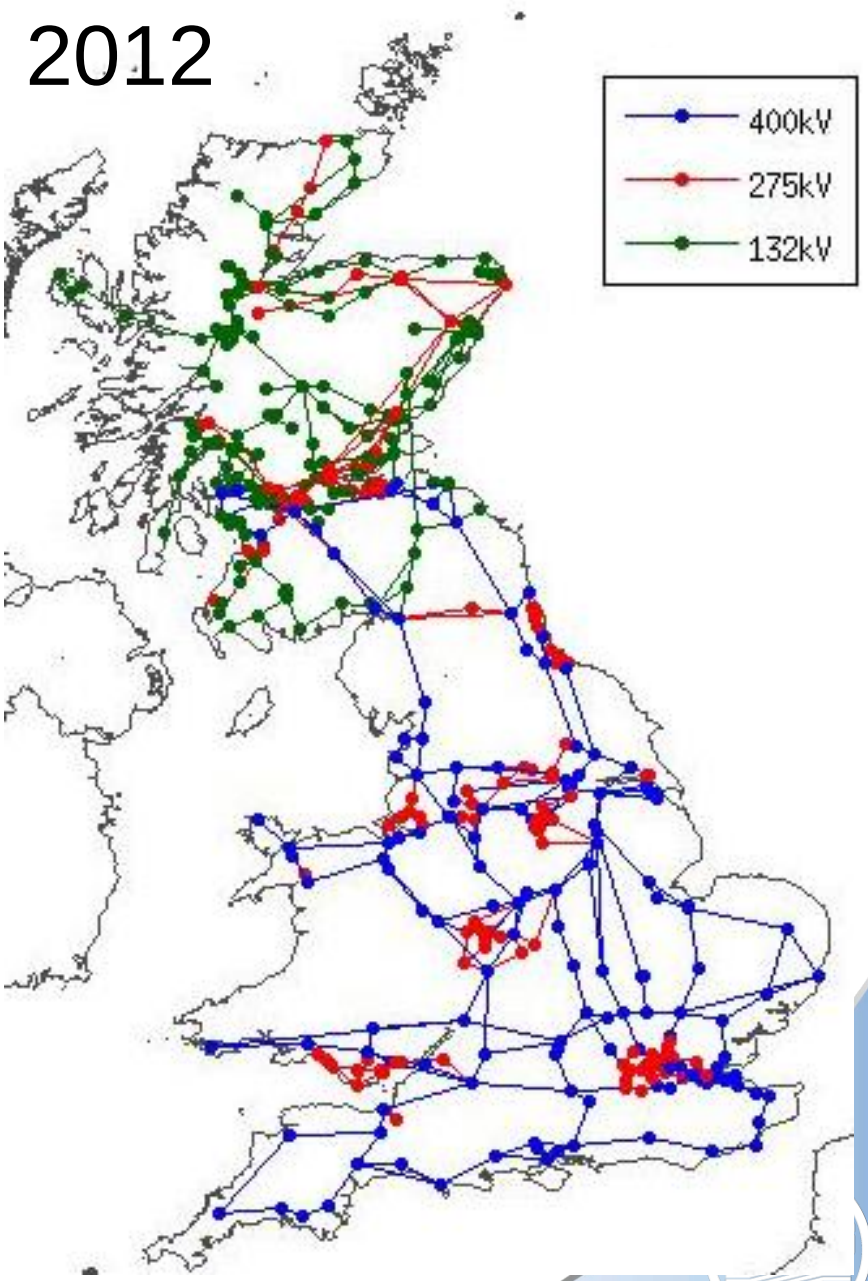
Geological attribution is a statistical procedure and provides conductivity distributions for each lithology.

Example: Conductivity distributions for 3 rock units with increasing clay content

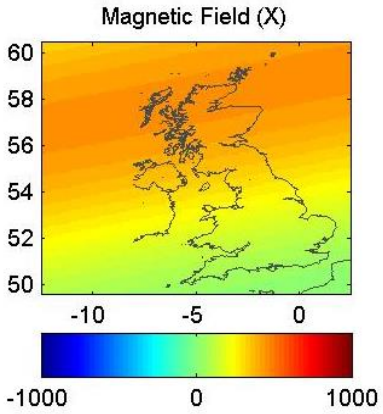


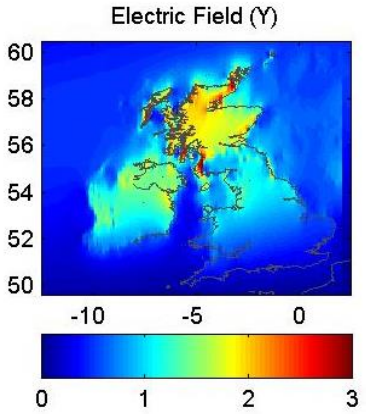
UK Power Network Model 2012

- Multiple transformers per location
- One connection between linked transformers (simplified)
- Transformer and earthing resistances partially provided by National Grid (remainder assumed constant)
- Line resistances calculated using transmission line impedances provided by National Grid
- 701 transformers with 1269 connections

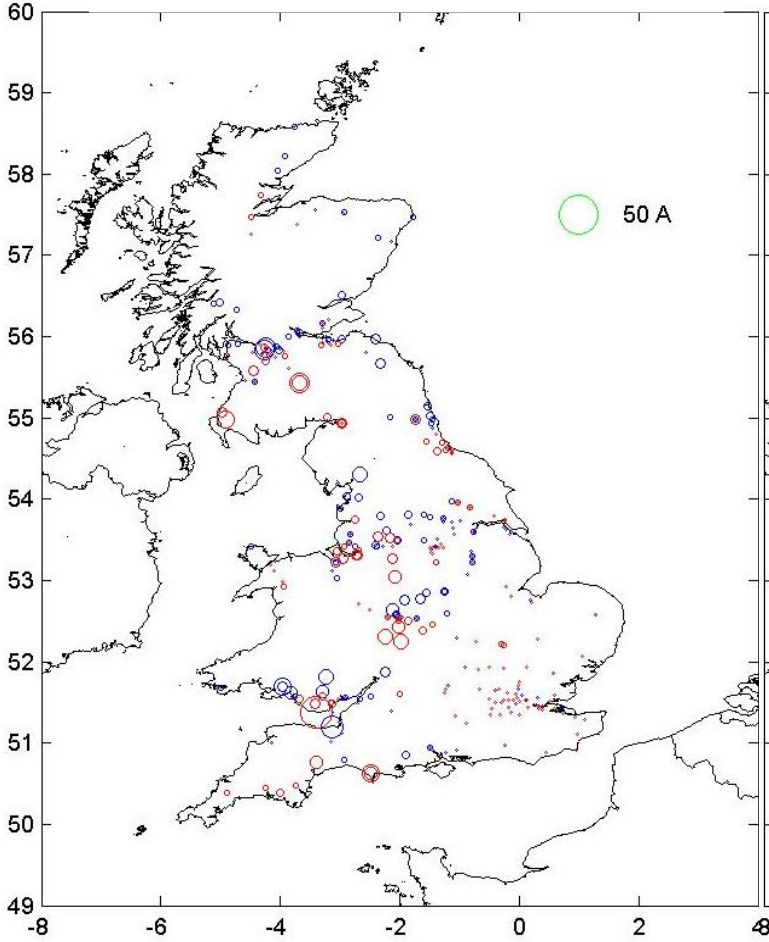


Model Test: Adding the 132kV Network

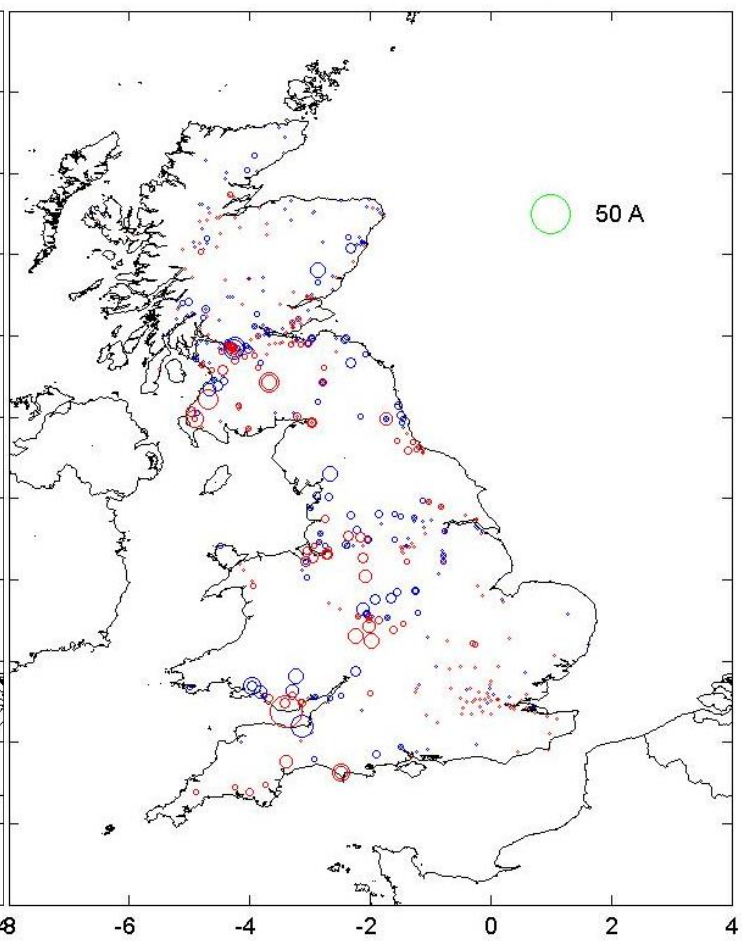




No 132kV



With 132kV



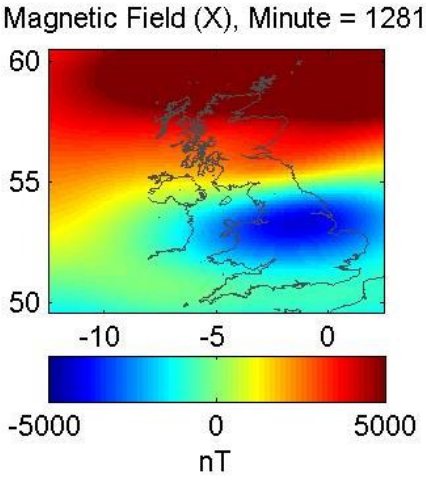
Electrojet modelled as a tapered cosine with field strength 450nT and frequency 120s

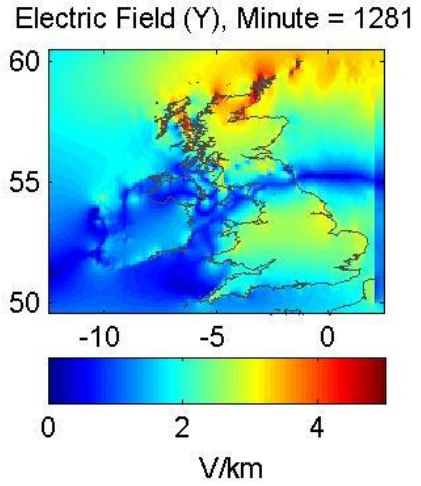
Model Test: Halloween Storm, Oct 2003

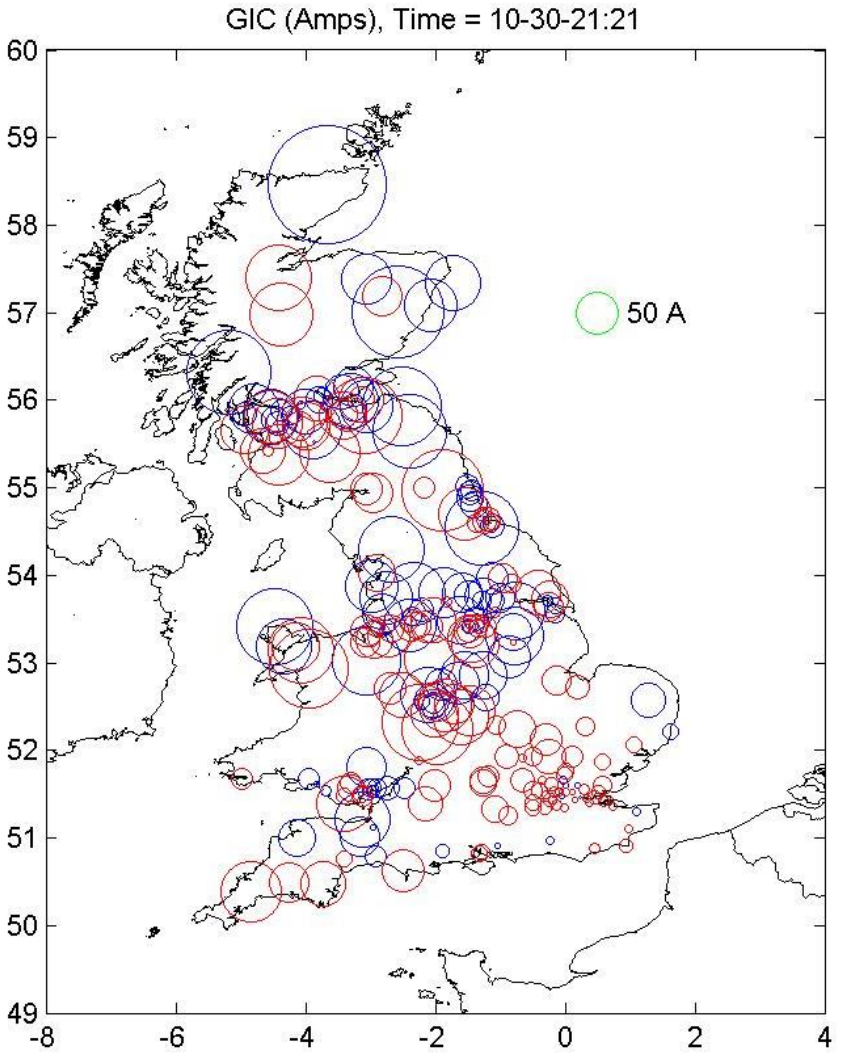
Notes:

- Oct 30th at 21:21 was storm peak in UK
- Simplified 400 kV model (252 nodes, 379 connections)
- Assumed six minute frequency of dH/dt
- Red = current into ground; blue = into grid

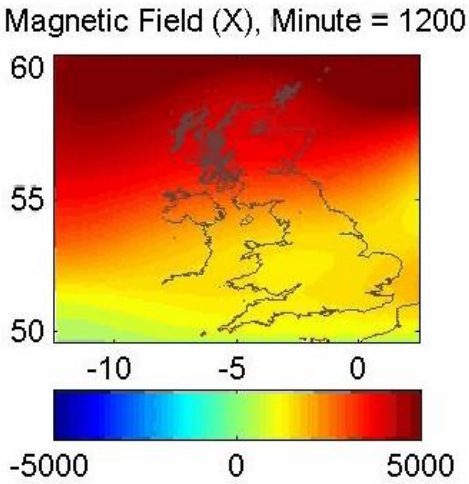
All 3 phases summed

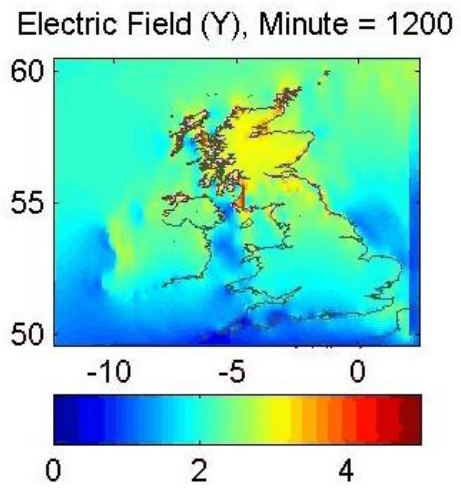


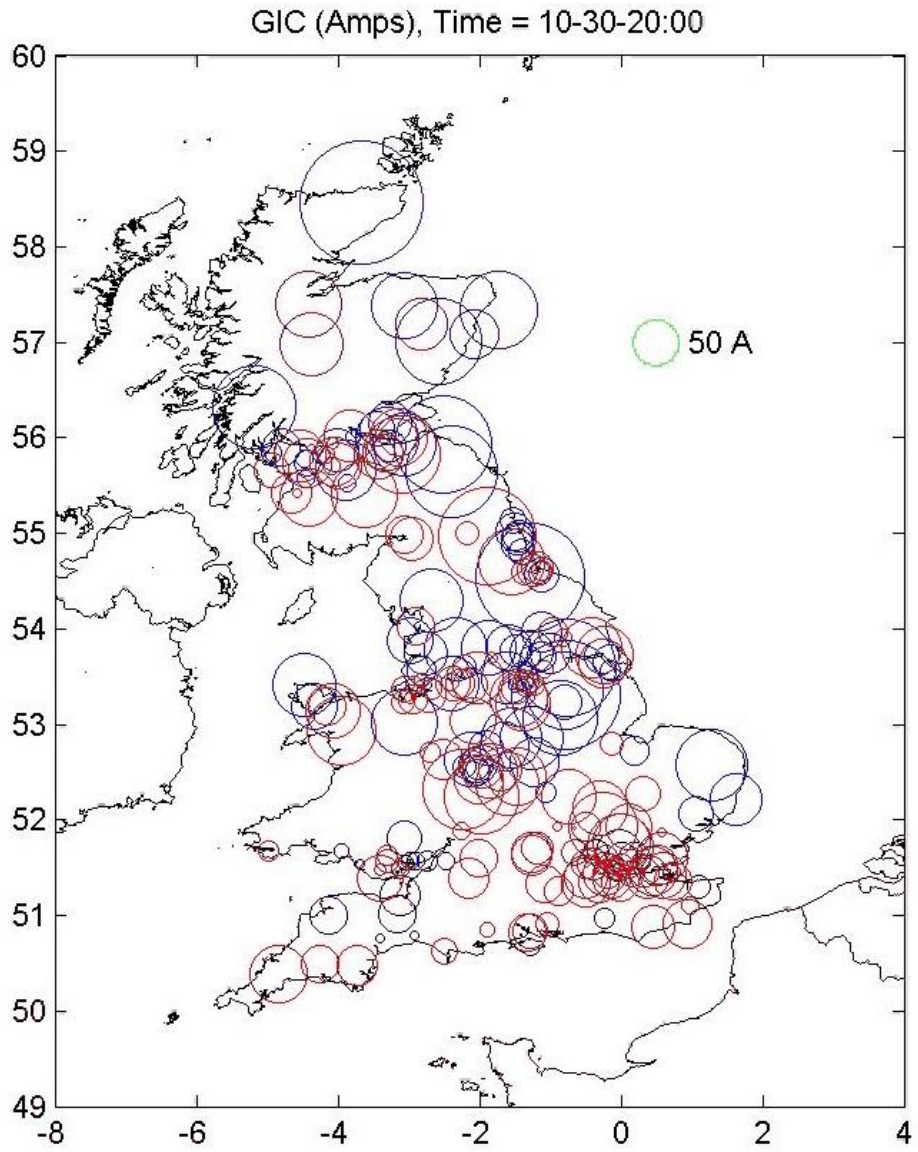




Model Test: ‘Carrington’ = Oct 2003 x8







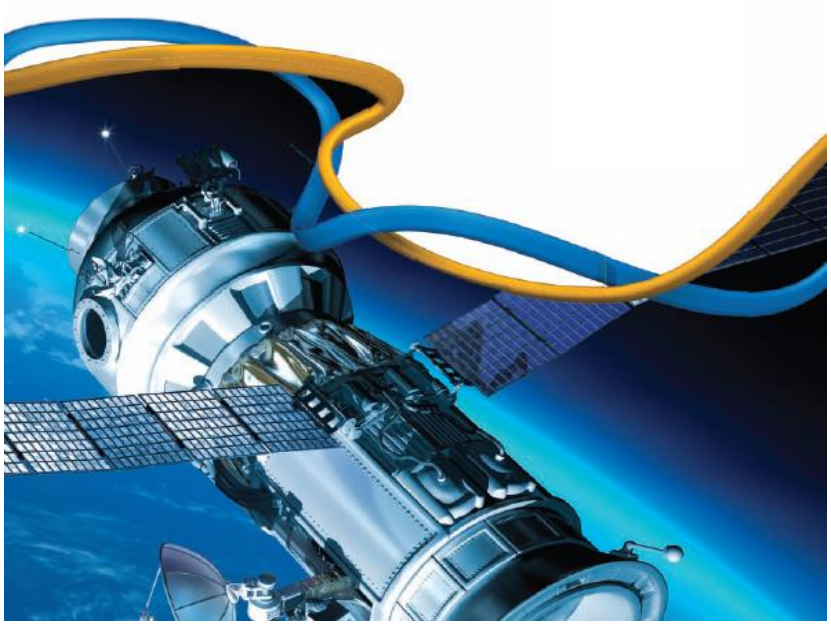
Beggan, Beamish, Kelly, Thomson, submitted to *Space Weather*, 2013

UK Royal Academy of Engineering, 2013

ROYAL ACADEMY OF ENGINEERING

Extreme space weather:
impacts on engineered systems and infrastructure

Summary report



www.raeng.org.uk/news/publications/

- Likely impact of a Carrington class storm
  - Periods of intermittent local/partial blackout during storm duration
  - Or national blackout lasting 6-12 hours
  - Damage to 13 super-grid transformers
  - Replaced over 8-16 weeks from existing spares
  - Risk to generator step-up transformers currently not known (not in the assessment)
- Preparation for a Carrington class storm
  - National Grid monitoring team takes advice from UK Met Office, BGS and international providers
  - Government coordination of response
  - Short term: need engineering mitigation
  - Long term: better monitoring and forecasting

Geo-Electric Field Monitoring

Objectives

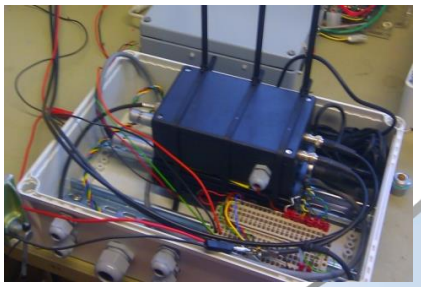
- Comparison of measured and modelled data to aid numerical model developments
- Longer term, project will provide magneto-telluric data for study of deep Earth conductivity

Project Summary

- Long-term measurements at Eskdalemuir, Lerwick & Hartland
- NS & EW electrode lines
- Electrode line length: 50 – 100 m
- Electrodes installed depth: 0.5–1.0 m
- Monitoring period: 2 -5 years

Installation Status

- First electrode pairs (EW & NS) installed at Eskdalemuir (September-October 2012)
- Installations at Lerwick & Hartland in May 2013



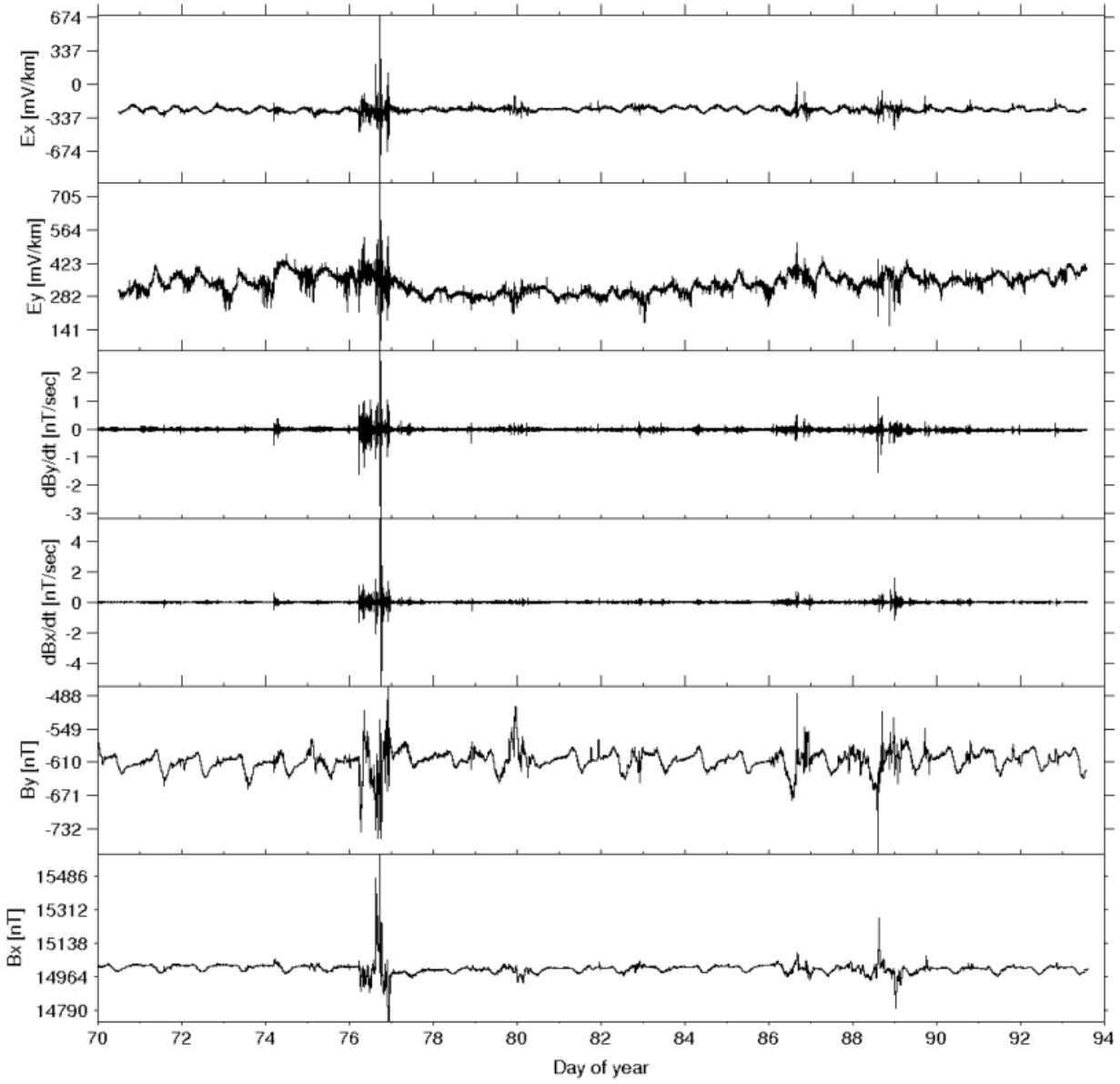
Data Example

Eskdalemuir Lerwick

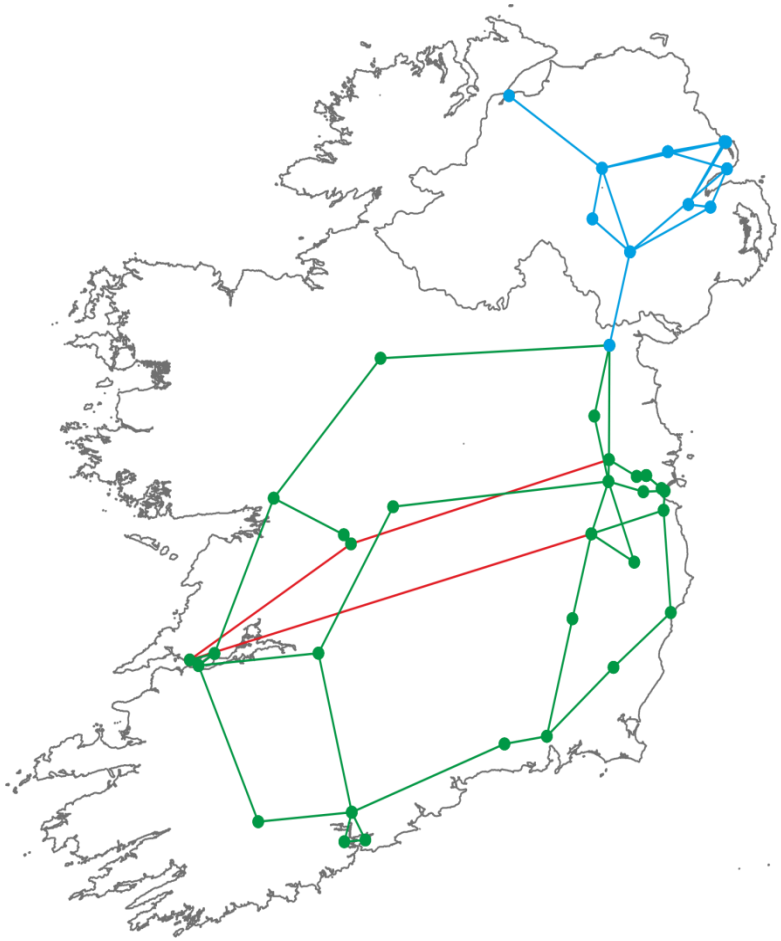
www.geomag.bgs.ac.uk/data_service/space_weather/geoelectric.html

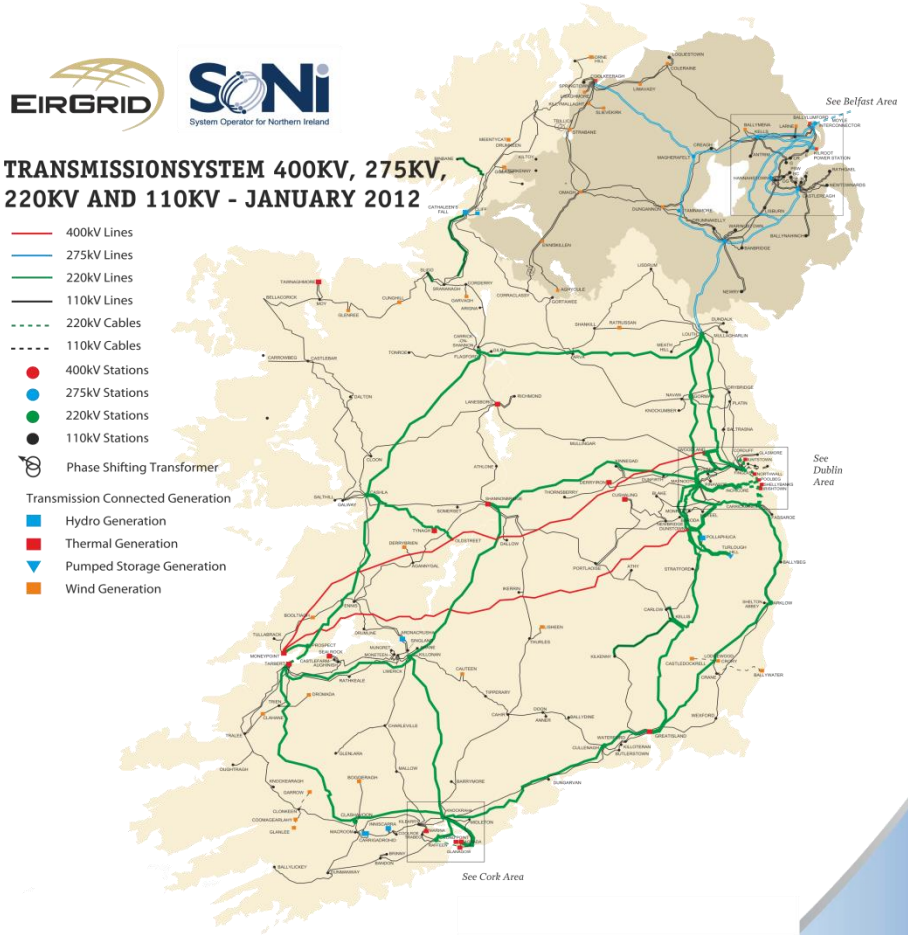
Remaining Challenges

- Potentially large dynamic range (µV to V)
- Long cable runs acting as antennas
- Unbalanced lines (no voltage zero reference)
- ‘Shorting’ of measurement (metal fences, buried cables)
- Changing conductivity (it’s Scotland)
- Cultural noise (50 Hz ground currents)
- **Comparing with modelled data – untangling effects of hardware, filters and local conditions**



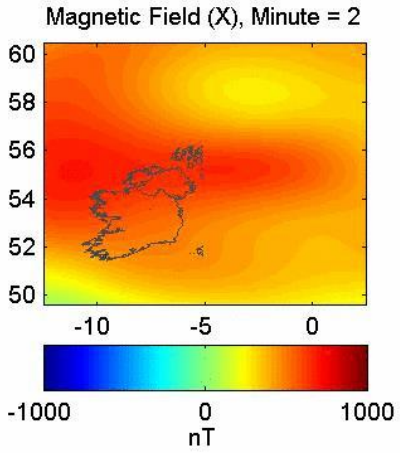
A First Irish Transmission Grid Model

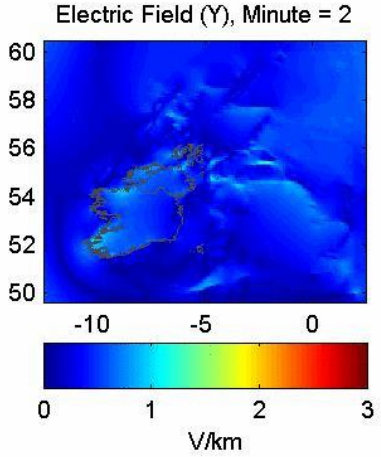


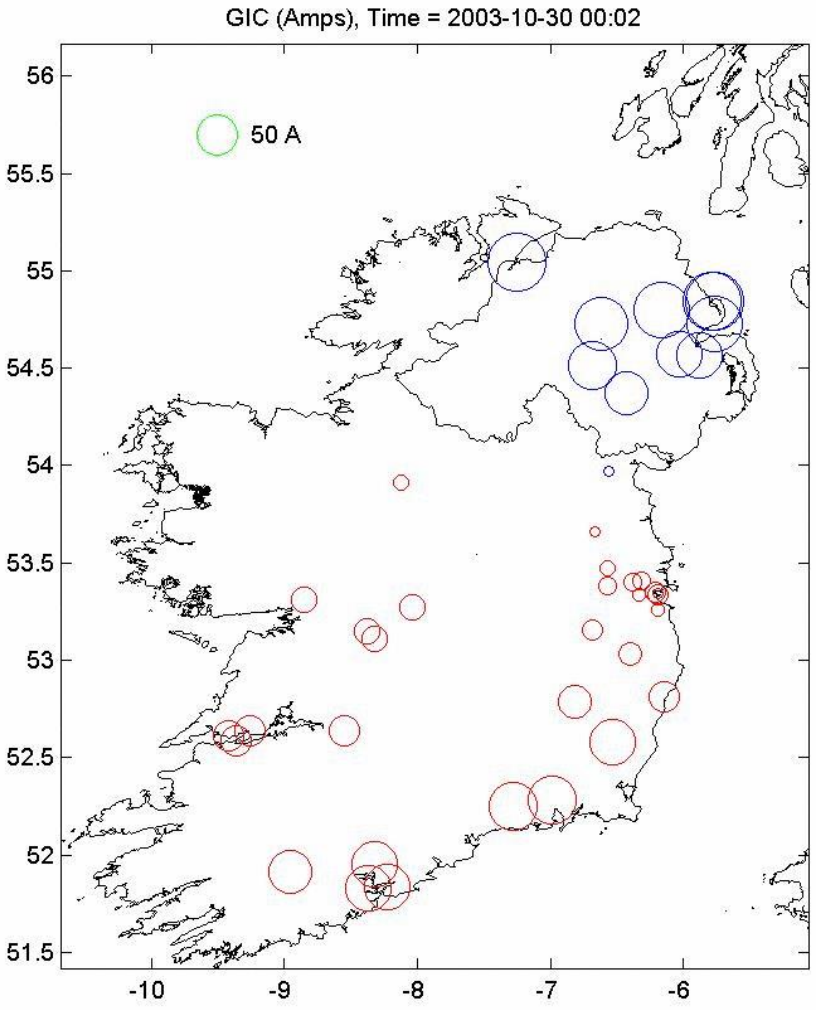


Acknowledgement: EirGrid

Irish GIC: A First Model of the ‘Halloween Storm’ of 2003







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Thanks for Your Attention