Geomagnetically induced currents in northern Europe during the April and July storms in 2000

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Introduction

Two severe magnetic storms in April and July 2000 caused major events of geomagnetically induced currents (GICs) in northern Europe. Besides data, we present some modelling results:

- Ionospheric equivalent currents with the method of elementary current systems.
- Calculation of GIC using geomagnetic recordings.
- Spectral analysis of GIC.

This poster deals with the April 6-7, 2000 storm. Corresponding material about the July storm is available on PC.

There is another poster about the April storm with global MHD simulations.

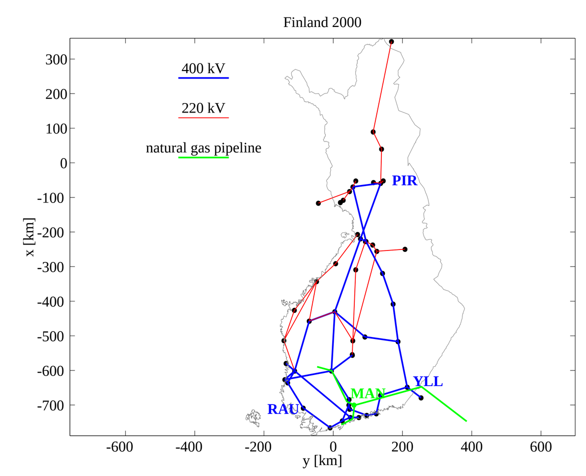


Figure 1: Finnish high-voltage power system and natural gas pipeline in 2000. GIC is recorded at the following 400 kV transformers: PIR = Pirttikoski, RAU = Rauma, YLL = Yllikkälä; and in the pipeline at Mäntsälä (MAN).

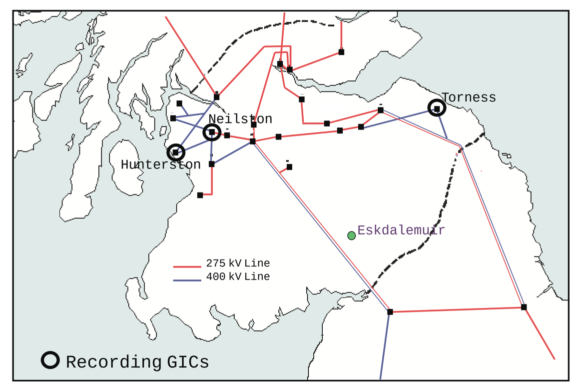


Figure 2: GIC measuring sites in the Scottish high-voltage power system. The geomagnetic observatory at Eskdalemuir is also shown.

Solar wind

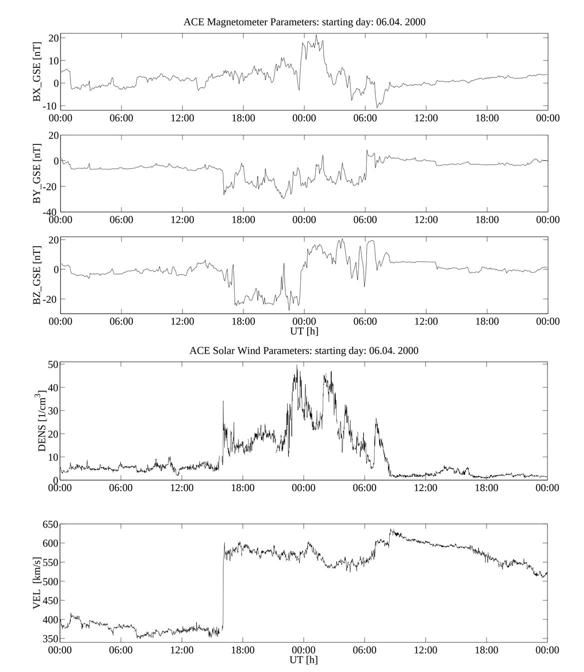


Figure 3: Solar wind magnetic field, density and speed on April 6-7, 2000.

Ground magnetic field

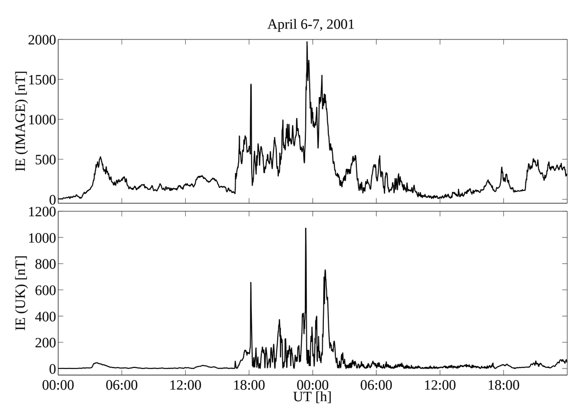


Figure 4: Difference of the maxima and minima of X ("IE index") at IMAGE magnetometer stations (upper panel) and at UK observatories (lower panel) on April 6-7, 2000.

GIC

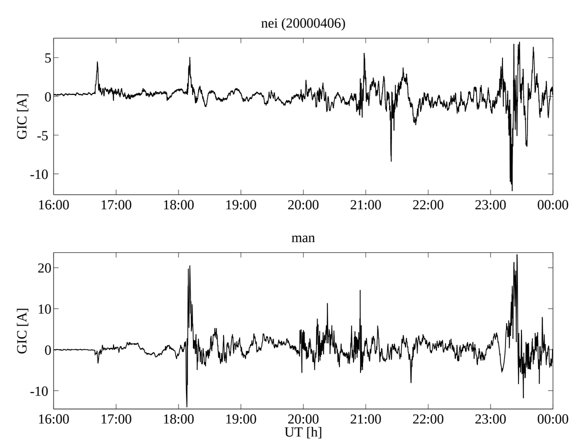


Figure 5: GIC in Scotland and Finland on April 6, 2000.
Upper panel : Neilston 400 kV transformer (Scotland).
Lower panel: Mäntsäla compressor station of the Finnish natural gas pipeline.

GIC and dB/dt

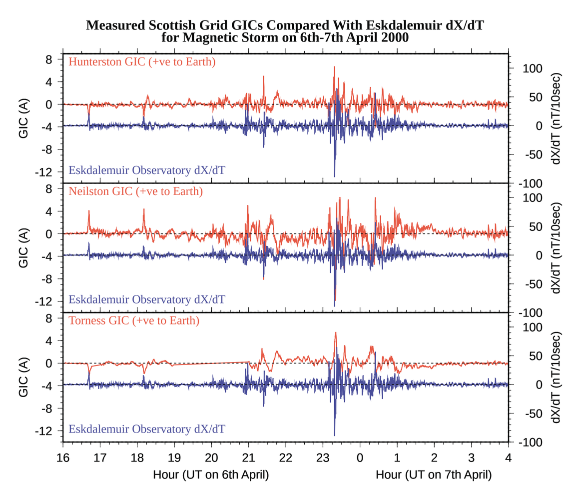


Figure 6: GIC and dX/dt in Scotland on April 6-7, 2000.

GIC and dB/dt

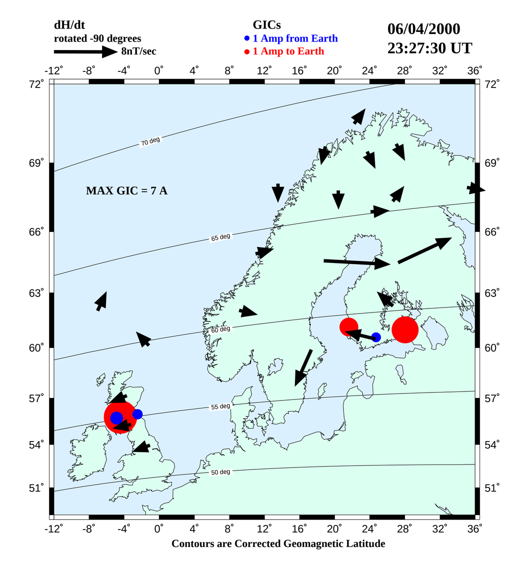


Figure 7: Snapshot of the animation of GIC and $d\mathbf{H}/dt$. To mimic the geoelectric field, $d\mathbf{H}/dt$ is rotated 90 degrees anticlockwise.

Ionospheric currents

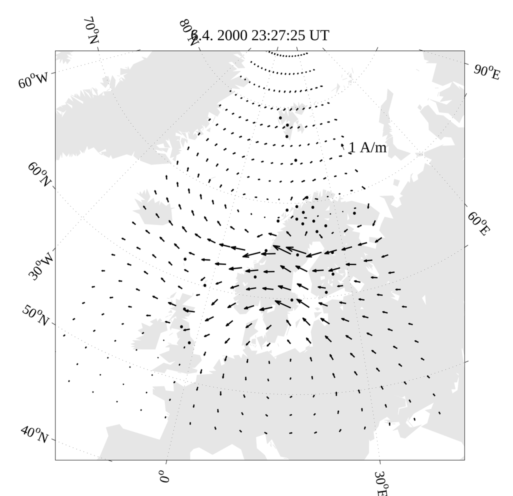
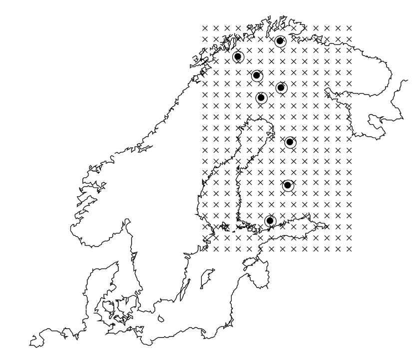


Figure 8: Snapshot of the animation of ionospheric equivalent currents determined by the spherical elementary current method. Black dots are magnetic observatories whose data were used. The main electrojet is located exceptionally south.

From B to GIC



B(BEAR)

B(IMAGE) –> B(Finland)

B(Finland) –> E(Finland)

E(Finland) –> GIC

Figure 9: An experimental method to calculate GIC using IMAGE magnetometer recordings was derived based on the measurements of the temporary BEAR array.

GIC modelling

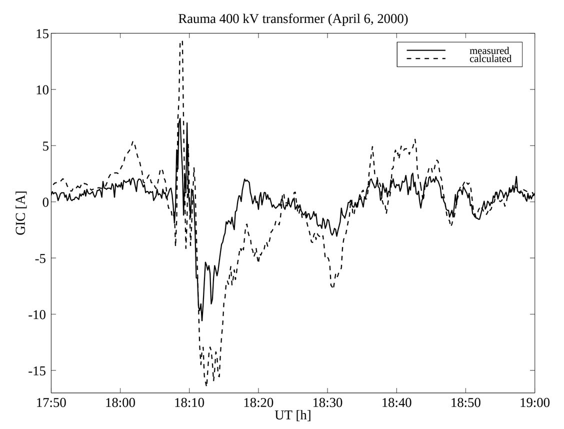


Figure 10: Measured and calculated GIC at the Rauma 400 kV transformer on April 6, 2000. Both curves have quite an identical shape, but amplitudes are different. Adjustment of the earth's conductivity model would improve the fit.

Frequency domain analysis

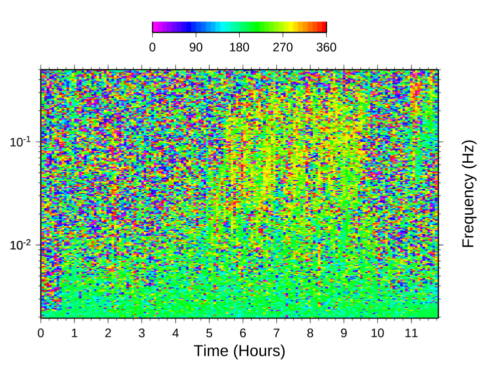


Figure 11: Relative phase of GIC at Hunterston and Neilston in the Scottish Power Grid, as a function of frequency. Time is hours from 16:00 UT, 6 April 2000. Phase relationship is constant in time (given sufficient signal power) however, changing phase with frequency could highlight underlying complexity of electric field driving GIC.

Were these storms large?

The daily Nurmijärvi A_k indices:

06.04. 119 (71. in 1953-2000)
07.04. 81
15.07. 157 (30.)
16.07. 84

Maximum GIC at Mäntsälä:

06.04. 23.0 A (2. in Nov 1998 - Jan 2001)
07.04. 14.2 A (7.)
15.07. 30.3 A (1.)
16.07. 16.6 A (4.)

Maxima of $|d\mathbf{B}/dt|$ at Nurmijärvi (XYZ, 10 s data):

06.04. 8.7 5.5 5.8 [nT/s]
07.04. 4.4 4.0 3.3
15.07. 9.5 7.7 6.5
16.07. 4.9 5.0 3.2

Consequently, they were large, but not extreme (in the GIC sense).

More ...

The following additional material is available on PC:

- Animations of GICs.
- Animations of ionospheric equivalent currents.
- Details about frequency domain analysis.

Please ask some of the authors for demonstrations.

See also the nearby poster:

Pulkkinen, A., M. Palmroth, E. Huttunen, P. Janhunen, O. Amm and A. Viljanen:

April 2000 storm:
Evaluation of global ionospheric convection and ground magnetic field variations given by global MHD simulation

Acknowledgements

Studies on geomagnetically induced currents are supported by Fingrid Oyj and Gasum Oy in Finland, and by Scottish Power plc in the United Kingdom.

ACE data were retrieved from CDAWeb.

We wish to thank all teams providing IMAGE and SAMNET magnetometer data.

GIC and dB/dt

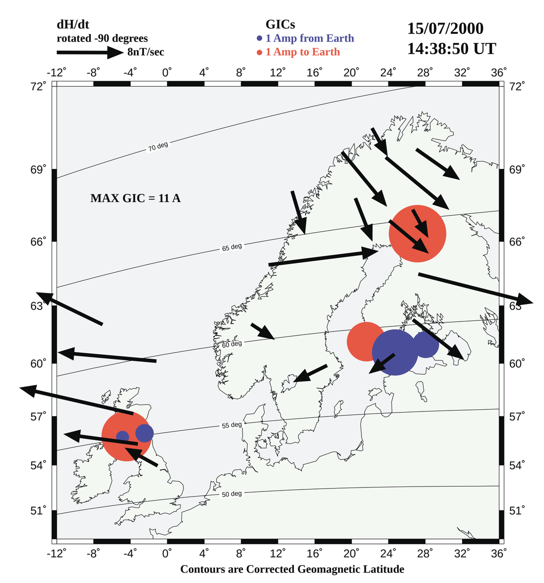


Figure 15: Snapshot of the animation of GIC and $d\mathbf{H}/dt$. To mimic the geoelectric field, $d\mathbf{H}/dt$ is rotated 90 degrees anticlockwise.