Real-time forecast service for geomagnetically induced currents

Lund Space Weather Center / Swedish Institute of Space Physics Team : H. Lundstedt, P. Wintoft, M. Wik, L. Eliasson

Summary

The goal of this pilot project is to develop a forecast service to be used by electrical power companies in southern Sweden. The forecast service will act as an early warning system to mitigate the effects of geomagnetically induced currents caused by space weather.

Introduction

Space Weather refers to "*Conditions on the sun and in the solar wind, magnetosphere, ionosphere, and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems and can endanger human life or health*".

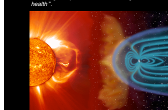

Fig. 1. This illustration shows a CME blasting off the Sun's surface in the direction of Earth. This left portion is composed of an EIT 304 image superimposed on a LASCO C2 coronagraph (Courtesy of ESA)

When a coronal mass ejection (CME), a huge plasma cloud, is expelled from the Sun and heading towards Earth, a magnetic storm can occur within the next few days. Electrons in the magnetosphere follow the magnetic field to the auroral oval where strong currents - electrojets - are created in the ionosphere.

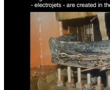

Fig. 2. A transformer at Salem, New Jersey, was damaged by the magnetic storm in March 1989.

When these currents change over time they will induce an electric field on the earth causing geomagnetically induced currents (GIC) to flow through transformer groundings and transmission lines. The transformers could get saturated causing increased transformer heating and in worst case - collapse of the whole power system.

Effects on power systems

On March 13-14, 1989, one of the worst geomagnetic storms took place. In Quebec induced currents caused a total collapse of the Hydro-Quebec power system leaving 6 million residents without power for about 9 hours.

At a nuclear plant in Sweden, a 5 C degree increase in the temperature of a rotor was measured.

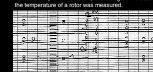

Fig. 3. GIC causing a 5 C degree increase in temperature of a rotor in a nuclear power plant in Sweden.

The solar wind is continuously measured by the ACE spacecraft located at Lagrange point L1 between the Earth and the Sun. Around midnight on September 24, 1998, the solar wind magnetic field turns strongly southward. At the same time there is a sudden increase in the density and the solar wind velocity.

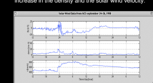

Fig. 4. Solar wind B_z-component, particle density and the velocity September 24-26, 1998.

GIC resulting from the CME was measured in a transformer grounding. At the same time induced potential (GIP) was measured 300 km from the transformer.

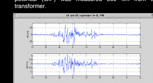

Fig. 5. Geomagnetically induced currents and geomagnetically induced potential for the 2 days in 1998.

Forecast Models

At the Swedish Institute of Space Physics in Lund geomagnetic activity is forecasted with the use of Neural Networks.

The geomagnetic activity depends on the current state of the magnetosphere and the solar wind input. This type of dynamic systems can be modeled by time delayed and recurrent networks.

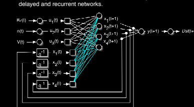

Fig. 6. Recurrent neural network with solar wind magnetic field, density and velocity as input and Dst as output.

Such models have been developed for ionospheric and geomagnetic indices, such as K_p [1], *Dst* [5], *AE* [3] and also for local magnetic field variations [2]. Direct GIC forecasting models have also been used at Oskarshamn in southern Sweden [4].

Proposed Solution

The service shall include a model that is able to forecast GIC from solar wind data.

Using solar wind data from ACE a first model forecast the time derivative of the geomagnetic field (dB/dt) at a given location in southern Sweden.

A second model uses the forecasted dB/dt to calculate the geoelectric field. A description of the power system and ground conductivity data is finally used to compute all the GICs in the power network.

Previous studies has shown that neural network is well suited for this task. Indata to the neural network will be solar wind density, velocity and magnetic field.

Datasets from ACE and the IMAGE magnetometer network will be used for training.

The output from the neural network will then be used to calculate the geoelectric field close to power system nodes. Earth's conductivity and a DC-model of the power system is then used to calculate GIC in all transformers and transmission lines.

Direct forecasting of GIC is also a possibility. Solar wind data will then be used to forecast GIC directly.

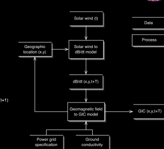

Fig. 7. Model for forecasting GIC in a power grid from solar wind data. The solar wind is sampled at time t and GIC is forecasted a time T ahead.

The Team consists of:

- Swedish Institute of Space Physics as Prime Contractor
- Finnish Meteorological Institute as Sub-contractor
- Elforsk AB as Contributor and User

Swedish power companies are the users and they will also take part in the project.

The service developer and provider is the Swedish Institute of Space Physics in collaboration with the Finnish Meteorological Institute. The forecast service shall be distributed by the Space Weather European Network (SWENET) and Regional Warning Center Sweden.

References

[1] Boberg, F., P. Wintoft, and H. Lundstedt, Real time Kp predictions from solar wind data using neural networks, *Phys. Chem. Earth*, *25*, 275–280, 2000.

[2] Gleisner, H., and H. Lundstedt, A neural network-based local model for prediction of geomagnetic disturbances, *J. Geophys. Res.*, *106*, 8425–8434, 2001.

[3] Gleisner, H., and H. Lundstedt, Auroral electrojet predictions with dynamic neural networks, *J. Geophys. Res.*, *106*, 24,541–24,550, 2001.

[4] Kronfeldt, I., *Forecasting and Calculating Geomagnetically Induced Currents*, A project within Ramverket för Elteknisk Utveckling at Sydkraft AB, Final Report, 2002.

[5] Lundstedt, H., H. Gleisner, and P. Wintoft, Operational forecasts of the geomagnetic Dst index, *Accepted for publication in Geophys. Res. Lett.*, 2002.

Contact information

Dr Henrik Lundstedt
Head of research group,
ISES Deputy director
Adress: Swedish Institute of Space Physics
Scheelevägen 17, 223 63 LUND
SWEDEN
Tel: +46 46 286 21 20
E-mail: henrik@lund.irf.se
Project: www.lund.irf.se