Geophysical Research Abstracts, Vol. 9, 03121, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-03121

The Sun, the solar wind and GIC effects in Sweden during geomagnetic superstorms

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Solar activity is responsible for geomagnetic storms and space weather effects at the Earth. The strength of a geomagnetic storm is dependent on the solar wind speed and magnetic field direction. Intense storms (Dst $<$ - 300 nT) occur, on average, every solar cycle and superintense storms (Dst $<$ - 500 nT) occur perhaps once a century. During a geomagnetic storm, an electric field is induced at the Earth's surface. It drives currents, so-called geomagnetically induced currents (GIC), in man-made conductors, such as electric power transmission grids, oil and gas pipelines, telecommunication cables and railway equipment. In general, GIC constitute a possible source of problems to technological systems. As Sweden is located close to the auroral oval there have been many GIC events during the past 150 years since the first electrical systems were installed. The world-record GIC (270 A) was measured in the earthing lead of a 400 kV transformer in southern Sweden during the magnetic storm on April 6, 2000, and on October 30, 2003, the city of Malmö at the southern coast of Sweden suffered from a power blackout caused by GIC. We have developed models that enable calculations of GIC in the Swedish 400 kV power system based on geomagnetic recordings. From historical events and past periods of intense and superintense geomagnetic storms, we estimate possible GIC magnitudes in today's power grid. For each storm we show and explain, if possible, the whole chain of processes from the Sun and the solar wind to GIC. We also discuss what kind of GIC events we can expect to impact the Swedish power grid during the next and future solar cycles.