Chapter 13

Ground Effects of Space Weather

Space weather effects on electric power transmission grids and pipelines

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Abstract

Space storms produce geomagnetically induced currents (GIC) in technological systems at the Earth’s surface, such as electric power transmission grids, pipelines, communication cables and railways. Thus GIC are the ground end of the space weather chain originating from the Sun. The first GIC observations were already made in early telegraph equipment about 150 years ago, and since then several different systems have experienced problems during large magnetic storms. Physically, GIC are driven by the geoelectric field induced by a geomagnetic variation. The electric and magnetic fields are primarily created by magnetospheric-ionospheric currents and secondarily influenced by currents induced in the Earth that are affected by the ground conductivity. The most violent magnetic variations occur in auroral regions, which indicates that GIC are a particular high-latitude problem but lower-latitude systems can also experience GIC problems. In power networks, GIC may cause saturation of transformers with harmful consequences extending from harmonics in the electricity to large reactive power consumption and even to a collapse of the system or to permanent damage of transformers. In pipelines, GIC and the associated pipe-to-soil voltages can enhance corrosion and disturb corrosion control measurements and protection. Modelling techniques of GIC are discussed in this paper. Having information about the Earth’s conductivity and about space currents or the ground magnetic field, a GIC calculation contains two steps: the determination of the geoelectric field and the computation of GIC in the

system considered. Generally, the latter step is easier but techniques applicable to discretely-earthed power systems essentially differ from those usable for continuously-earthed buried pipelines. Time-critical purposes, like forecasting of GIC, require a fast calculation of the geoelectric field. A straightforward derivation of the electric field from Maxwell’s equations and boundary conditions seems to be too slow. The complex image method (CIM) is an alternative but the electric field can also be calculated by applying the simple plane wave formula if ground-based magnetic data are available. In this paper, special attention is paid to the relation between CIM and the plane wave method. A study about GIC in Scotland and Finland during the large geomagnetic storm in April 2000 and another statistical study about GIC in Finland during SSC events are also briefly discussed.

Keywords Geomagnetically induced currents, GIC, geoelectric field, geomagnetic disturbances, geoelectromagnetics, plane wave, complex image method

1. INTRODUCTION

At the Earth's surface, space weather manifests itself as geomagnetically induced currents (GIC) flowing in long conductors, such as electric power transmission networks, oil and gas pipelines, telecommunication cables and railways systems. In power grids, GIC cause saturation of transformers, which tends to distort and increase the exciting current. It in turn implies harmonics in the electricity, unwanted relay trippings, large reactive power consumption, voltage fluctuations etc., leading finally to a possible black-out of the whole system, and to permanent damage of transformers (Kappenman and Albertson, 1990; Kappenman, 1996; Erinmez et al., 2002b; Molinski, 2002).

In buried pipelines, GIC and the associated pipe-to-soil voltages contribute to corrosion and disturb corrosion control surveys and protection systems (Boteler, 2000; Gummow, 2002). Telecommunication devices have also experienced GIC problems (Karsberg et al., 1959; Boteler et al., 1998; Nevanlinna et al., 2001). As optical fibre cables do not carry GIC, space weather risks on telecommunication equipment are probably smaller today than previously. However, it should also be noted that metal wires are used in parallel with optical cables for the power to repeat stations. There are not many studies of GIC effects on railways, and to the knowledge of the authors of this paper, the only publicly and clearly documented case has occurred in Sweden where GIC resulted in misoperation of railway traffic lights during a geomagnetic storm in July 1982 (Wallerius, 1982). (A private communication with a Russian scientist indicates that space weather has caused problems in Russian railway systems, too.)