Journal of Atmospheric and Solar-Terrestrial Physics 67 (2005) 701–708

Journal of ATMOSPHERIC AND SOLAR-TERRESTRIAL PHYSICS

www.elsevier.com/locate/jastp

Averages of geomagnetically induced currents (GIC) in the Finnish 400 kV electric power transmission system and the effect of neutral point reactors on GIC

Risto Pirjola*

Finnish Meteorological Institute, Space Research Unit, P.O. Box 503, FIN-00101 Helsinki, Finland

Received 2 February 2004; received in revised form 21 June 2004; accepted 4 January 2005

Abstract

Geomagnetically induced currents (GIC) in technological systems are ground effects of space weather. In electric power transmission networks, GIC may produce problems by saturating transformers. Thus, GIC flowing into and from the Earth through transformers are more important in practice than GIC in transmission lines. In this paper, we show by considering a simple idealised model and by numerical computations about the Finnish 400 kV system that, on the average, earthing GIC, i.e. transformer-neutral-to-ground GIC, are smaller than line GIC, which should thus be regarded as a good observation from the practical point of view. It should, however, be noted that GIC greatly vary from site to site in a system and from system to system. Installing neutral point reactors in earthing leads of transformers, as has been done in Finland, tend to decrease GIC due to their large resistance. Computations of GIC presented in this paper quantitatively demonstrate the effects of reactors on GIC in the Finnish power system. It is seen that earthing GIC magnitudes decrease at the stations with reactors but the average decrease is not very large. Stations without a reactor usually experience an increase of GIC when reactors are installed at other stations.

Keywords: Space weather; GIC; Power grid; Transformer; Neutral point reactor

1. Introduction

Geomagnetically induced currents (GIC) in technological systems, such as electric power transmission grids and oil and gas pipelines, are the ground manifestation of space weather (e.g. Boteler et al., 1998). GIC are a possible source of problems to the system. In power networks, this is due to saturation of transformers, and in pipelines, troubles associated with corrosion and its control arise.

The whole space weather chain originating from the Sun is very complicated, and its full understanding, which should be aimed at for being able to manage with space weather risks, is a hard task. Development of mitigation techniques against GIC in a system requires knowledge about basic principles of the flow of GIC and about the effects of different network parameters on GIC magnitudes. Pirjola (2002) examined the effect of the direction of the external horizontal geoelectric field on the resulting GIC in a simple fictitious power system. He also showed that installing series capacitors in transmission lines, which block the flow of GIC, is not straightforward as concerns decreasing GIC risks. A corresponding conclusion of the effect of capacitors on

*Tel.: +358 9 19294652; fax: +358 9 19294603.
E-mail address: risto.pirjola@fmi.fi.

1364-6826/$ - see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jastp.2005.01.004

GIC is also presented by Erinmez et al. (2002), who consider the entire high-voltage power system of England and Wales.

Measurements of GIC have been carried out in the Finnish high-voltage power system since 1977 (e.g. Viljanen and Pirjola, 1994). The GIC data obtained in the beginning of the recordings show clearly larger values than those recently observed. For example, during the great space storm in October–November 2003, GIC of only about 40 A was measured whereas the largest GIC ever measured in Finland was about 200 A in March 1991. Both measurements were made in the earthing lead of the 400 kV transformer at the Rauma station (not yet included in the old configuration in Fig. 1 but located between stations 4 and 7 very near the latter). It should also be noted that the features of the October–November 2003 and March 1991 geomagnetic storms were quite different. The large GIC magnitudes in March 1991 emphasise the fact that it is the time derivative of the magnetic field that plays an important role regarding GIC, not the amplitude of the magnetic field variation.

The installation of neutral point reactors in earthing leads of transformers at several stations is referred to when looking for reasons for diminished GIC values in the Finnish system. The effect of neutral point reactors on GIC in the Finnish 400 kV system are studied by numerical computations in this paper, and it is demonstrated that GIC magnitudes do decrease but not drastically on the average.

Since problems caused by GIC in a power system arise from transformer saturation GIC flowing through transformers into or from the Earth are important while GIC in transmission lines are of minor practical significance. It is believed that earthing GIC are generally smaller than transmission line GIC. Note that the term "earthing GIC" frequently used in this paper refers to GIC from (or to) a transformer neutral to (or from) the ground, which would correspond to the power industry terminology. An explanation to the statement about larger line GIC than earthing GIC is that a rotational horizontal geoelectric field can drive GIC in line loops even without any current flowing into or from the Earth. Pirjola (2000) theoretically demonstrated this by considering a simple loop without any earthings. In this paper, we perform model calculations of GIC in the Finnish 400 kV power grid by using a uniform geoelectric field, which is thus irrotational, and show that even then transmission lines tend to carry larger GIC than those in the earthings. The issue is also considered by an idealised theoretical model.

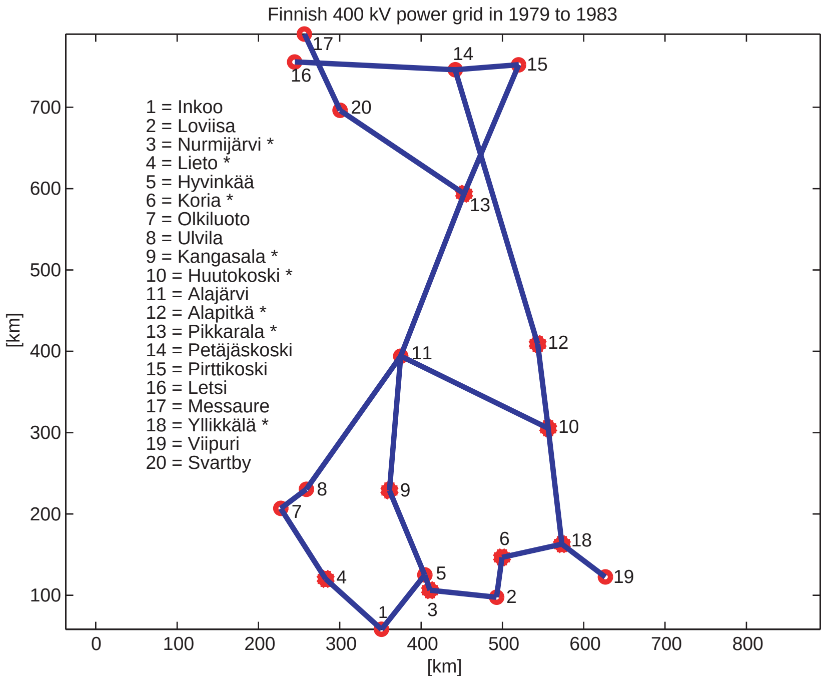

Fig. 1. Finnish 400 kV electric power transmission grid in its configuration valid 1979–1983. The transmission lines between the stations are approximated to be straight in the figure. The lines between stations 11 and 13 and between stations 18 and 19 are actually double lines. Stations equipped with a neutral point reactor for studies of the effects on GIC in this paper are indicated by a larger circle and by an asterisk in the list. The grid lies at geographic latitudes of about 60–67°N and at geomagnetic latitudes of about 57–64°N. No major changes have taken place in the grid map since 1983.