INDUCTION IN POWER TRANSMISSION LINES DURING GEOMAGNETIC DISTURBANCES*

RISTO PIRJOLA
Finnish Meteorological Institute, Division of Geomagnetism, Box 503, SF-00101 Helsinki 10, Finland

Abstract. The electric field associated with geomagnetic disturbances gives rise to potential differences at the Earth's surface. Thus, currents are induced in power transmission lines which are earthed at both ends through transformers. The currents vary so slowly with time that they can be considered direct currents. The phenomenon has been studied in Finland for some years, and in connection with this research induced currents have been measured at four places by recording the current from the transformer neutral into the Earth. These measurements are considered in this paper. In addition, theoretical calculation of the potential differences and of the currents is discussed.

1. Introduction

Time variations in the electric current system of the Earth's ionosphere and magnetosphere are in complicated, although as yet not completely understood ways mainly consequences of the influences of the Sun. These variations cause fluctuations in the geomagnetic field. The irregular fluctuations are called geomagnetic disturbances or geomagnetic storms. According to basic electromagnetic theory, it is clear that an electric field is associated with these disturbances. The magnetic disturbances and the electric field are also influenced by secondary currents induced within the Earth.

As a result of the above-mentioned electric field, potential differences occur between separate points at the Earth's surface. These voltages give rise to electric currents in power transmission lines which are earthed at both ends through transformers (Figure 1). Similar currents occur between two earthing points in all metallic structures, such as telephone cables, oil and gas pipelines, and rails. This paper, however, concentrates upon power line currents. The time variations of the potential differences are slow, so that the currents can be regarded as direct currents compared to 50 Hz. The inconveniences such currents may cause are not treated in detail in this paper. We should mention that the current can cause saturation of transformers. This implies harmonics in the electricity. In addition, false trippings of relay protection may occur. Saturation can also even lead to overheating in a transformer, resulting in permanent damage.

On the Earth's surface the geomagnetic disturbances are most intense and their occurrence most frequent in the north and in the south at and close to the so-called auroral zones. Hence, the problem concerning the induction in power transmission lines is naturally greatest at and near the auroral zones, as for example in Finland. Another fact that increases the significance of the problem in Finland is the lower soil conductivity.


Copyright © 1983 by D. Reidel Publishing Co., Dordrecht, Holland, and Boston, U.S.A.
Fig. 1. Potential differences at the Earth's surface cause electric currents in power transmission lines earthed at both ends through transformers (Albertson and Van Baelen, 1970).

(cf. Persson, 1979). In general, the potential differences are more significant in the east–west direction than in the north–south direction.

No noteworthy harmful effects from induced currents in power lines have been observed in Finland. Because of the importance of the subject, research work has, however, been going on for some years. In connection with this research currents induced in 400 kV lines have been measured by recording the currents from transformer neutrals into the Earth.

2. Calculation of the Induced Current

As mentioned above, the time variations of the potential differences connected with geomagnetic disturbances are slow. Therefore the current induced in an isolated power transmission line section earthed at both ends (Figure 1) can, with a high degree of accuracy, be calculated simply by dividing the potential difference between the earthing points in the absence of the line by the total direct current resistance of the system (Albertson and Van Baelen, 1970), see also Campbell (1978). The total resistance includes the resistances of the line, of the transformers (all three phases in parallel) and of the earthings.

Thus, the main difficulty in the calculation of the induced current in a power system is the determination of the electric field at the Earth's surface. Nevertheless, one has to bear in mind that a power transmission system need not be an isolated section as in Figure 1, but it may continue galvanically after the earthing point. In more complicated situations the calculation of the current is not just a division, but certain circuits have to be treated. However, the calculation of the potential differences still constitutes the greatest difficulties.

If the primary ionospheric and magnetospheric sources of the disturbing electromagnetic field and the electrical properties of the Earth are known, the induced electric field at the Earth's surface can in principle be calculated utilizing Maxwell's equations and boundary conditions. The real situation is, however, so complicated that it must be simplified considerably in theoretical discussions.