CHARACTERISTICS OF GEOMAGNETICALLY INDUCED CURRENTS PRODUCED BY DIFFERENT TYPES OF GEOMAGNETIC ACTIVITY

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Abstract:

Geomagnetically induced currents (GIC) in power systems are driven by the induced electric field, E, associated with the magnetic field variations, B. At the frequencies we are concerned with (periods from seconds to hours) the power system acts as a purely resistive network; hence the GIC are in-phase with the electric field variations. Therefore, the frequency dependence in the GIC to B relationship comes purely from the E to B relationship which is defined by the surface impedance of the Earth.

The magnetic field at the Earth's surface consists of two parts: one due to "external" sources, usually electric currents in the ionosphere or magnetosphere, and the other due to "internal" sources, ie induced electric currents in the Earth. While the electric field at the Earth's surface may be due to the rate of change of the external magnetic field, it is also driving the induced currents and hence is directly related to the internal magnetic fields they produce. Thus the relation between the electric field and the total observed magnetic field is rather ambiguous.

For a uniform earth, E can be related to B by a transfer function that is dependent on the square root of frequency. Conversely E can also be related to dB/dt by a transfer function that is dependent on the inverse of the square root of frequency. The former is analogous to the response of a high-pass filter while the latter is analogous to the response of a low-pass filter. Both are acceptable ways of representing the earth transfer function and indicates that either B or dB/dt can be used in determining the level of GIC.

We investigate a number of recent magnetic disturbances to determine the relationship between geomagnetically induced currents and magnetic field variations. Although some features show an apparent relation between GIC and dB/dt, a number of observations have shown a closer correspondence with the magnetic field, B. To examine this further, spectrograms are used to illustrate the typical frequency content of different types of geomagnetic activity. We also study how different layered earth model affects the frequency response of the Earth transfer functions and how this affects the apparent relation between GIC and dB/dt or B. We show that the earth response depends on the

conductivity of the layers and their order down from the surface. Also, as the skin depth for the induced currents depends on frequency, the layers and conductivity "seen" by different types of geomagnetic activity varies depending on their frequency content. Thus the response between GIC and B or dB/dt varies depending on the frequency content of the disturbance and the conductivity structure of the Earth.