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Geomagnetically Induced Currents: Progress and Issues

Alan Thomson
British Geological Survey, Geomagnetism, Edinburgh, United Kingdom (awpt@bgs.ac.uk, +44 131 650 0257)

Geomagnetically induced currents (GIC) are a hazard to conducting networks such as high-voltage power and pipeline grids. GIC have been known for decades to affect power systems at higher latitudes (e.g. Europe and North America), although more recently GIC have also been found to affect power networks at middle and lower latitudes. Mitigating the effects of GIC remains an issue for the power and pipeline industries and for governments concerned with the societal and economic implications.

To understand, e.g. to model and predict, GIC in conducting grids needs expertise drawn from electrical engineering, geophysics and space weather science – a truly multi-disciplinary undertaking. In terms of geophysics and space physics, issues such as Earth structure (e.g. 3D versus 1D mantle and lithospheric conductivity structure), ocean/continent conductivity contrasts, ionospheric current systems and their variability and Sun-Earth magnetic interactions are all relevant.

The start of solar cycle 24 provides an opportune time to consider the status of GIC research and to assess what new studies are required in geophysical modelling and in hazard analysis. What do we need to improve on to better specify/predict GIC flowing in power grids, from 'up-stream' observations of coronal mass ejections through to geomagnetic field measurements made during magnetic storms?

In this invited review we will consider aspects of a) Measurement: how do we measure GIC in grids; b) Analysis: how do measured GIC relate to geophysical and space physics data; c) Modelling: what methods exist for modelling GIC, again in relation to other data, and how accurate are models; and d) Prediction: how predictable are GIC and what are the implications for, e.g., the power industry and national governments.

We will review the more recent developments in GIC and related geomagnetism and space weather science. We will outline what issues are widely believed to now be understood and what issues remain to be addressed. Throughout, the relationship between GIC studies and geomagnetism science in general will be stressed. Issues around providing GIC-related services to industry will also be mentioned and a proposed study of GIC in the pan-European high-voltage power grid will be described.