Geoelectromagnetics with the Geophysical Instrument Combination of Hydro-Québec, AUTUMNX, and USArray Magnetotellurics

*Martin G Connors[1], Sébastien Guillon[2], Adam Schultz[3], Naoto Imamura[3]

1. Athabasca University, 2. Hydro-Québec TransÉnergie, 3. Oregon State University

Geoelectromagnetics is a term used by Bolduc et al. (2000) regarding a pioneering study in which electric fields near a part of the Hydro-Québec transmission network were measured during an intense auroral event. To fully characterize space weather effects on an electric power transmission network, we must proceed from the source currents and their variations, through the changing magnetic fields near Earth's surface, to the electric fields induced in the Earth and to some extent in the conducting structures directly, to electric currents flowing in the grid, and finally to the effects of such currents, ranging from voltage distortion to possible equipment damage. The more data can be measured at each link in this complex chain, the better will be our ability to monitor current events in a precautionary manner and assess the robustness of the grid to varying levels of stress.

The Hydro-Québec network has had enhanced monitoring capabilities (as well as improved ability to deal with geomagnetic stresses) since 1989 (Guillon et al., 2016). The last link of the chain, effects, is able to be well quantified, especially through measures of voltage distortion. Direct measurements of transformer grounding currents, essentially the geomagnetically induced currents (GIC) themselves, are available at a few points. The AUTUMNX magnetic network (Connors et al., 2015) complemented grid instrumentation in Québec starting in 2014, and has produced a new view of the association of magnetic variations with signals in the grid. Magnetotellurics (MT) tends to operate in campaign mode, but also measures the electric field, including at relevant low frequencies, giving a more complete indication of the geoelectromagnetic environment while also providing measurements of the frequency dependent electromagnetic impedance of the ground, which can be used to reconstruct the electrical conductivity structure of the Earth's crust and mantle.

We illustrate these comprehensive geoelectromagnetic measurements with the case of the magnetic storm of September 7-9 2017, during which the NSF EarthScope MT array installed by Oregon State University was operating in the northeastern US, near the Hydro-Québec grid, at a time when the electrojet had expanded southward. We find a close correlation of times of large magnetic field variation, measured electric fields, and harmonic distortion in the grid.

While we note the complications stressed by Love et al. (2018), we feel that the enhanced MT monitoring advocated by Love et al. (2016), would give more knowledge of geological structure and geoelectric response in northeastern North America. In this way, our understanding of GIC would be greatly improved, in the areas of understanding basic processes and hazard assessment.

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