GMD Impacts on High Voltage Power Grids – Lessons Learned

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Abstract—Over the past 33 years a great deal has been learned about how geomagnetic disturbances (GMDs) affect high voltage power grids. Many researchers have analyzed the nature of the many large and small geomagnetic storms that have occurred since the infamous Quebec power grid failure in March 1989, and have evaluated through both analysis and data reviews how power grids have been affected. This paper will review some of the major accomplishments over the past 33 years in our understanding. Of course the problem is not completely solved, as we do not know what the Sun will do in the future, nor have we been successful in applying protection techniques on a large scale to vulnerable power grids.

Keywords- Geomagnetic storms, GMDs, high-voltage power grids

I. BACKGROUND

This paper reviews (over the past 33 years) the study of geomagnetic storms and their impacts on high-voltage transmission grids. Discussion of some early papers and references will be part of the presentation. Much of the interest in geomagnetic storms was motivated due to the voltage collapse of the transmission grid in Quebec, Canada, due to the sudden onset of a significant geomagnetic storm on March 13, 1989. Since measurements of the magnetic field that initiated the grid collapse were available near the power grid itself and the power grid operators had timed data regarding the operation of the grid itself, it is clear that the voltage collapse occurred over a period of only 92 seconds [1].

II. TOPICS TO BE DISCUSSED

1. Evaluation of the need for faster magnetometer measurements
2. The need for time-domain modeling techniques
3. Graphical display of measured and calculated fields and induced currents
4. Evaluation of deep earth conductivity profiles
5. Modeling of large grids and end-to-end validation
6. Relationship of induced currents and the voltage level of power grids
7. Impacts due to different types of geomagnetic storms
8. Vector behavior of the "incident" magnetic fields
9. Edge of the grid, the ocean effect and line length considerations

II. EXAMPLE RESULTS

Two examples of important developments are illustrated below. Each of the topics and their importance will be discussed during the presentation. Figure 1 illustrates ground contours of the measured magnetic fields with the available 1-minute data. Note the rapid changes with time.

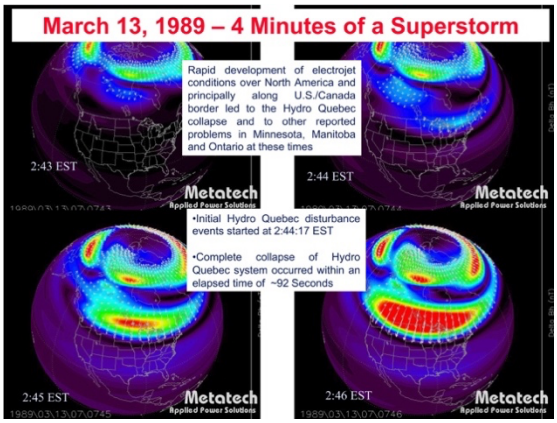

Figure 1. Graphical frames of the March 13, 1989 Quebec electrojet storm (magnitude of measured B-fields is shown) [2].

Figure 2 illustrates the variation of the direction of the measured horizontal B-field with time during a large GMD event in Scandinavia in 1991.

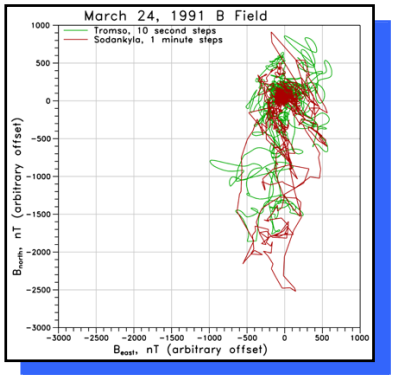

Figure 2. Measurements of the B-field vector with time [1].

REFERENCES

[1] "Understanding of geomagnetic storm environment for high voltage power grids," CIGRE Technical Brochure 780, October 2019.

[2] J. Kappenman, "Geomagnetic Storms and Their Impacts on the U.S. Power Grid,", Oak Ridge National Laboratories, Meta-R319, January 2010.