URSI GASS 2023, Sapporo, Japan, 19 – 26 August 2023

Space weather disturbances in electrical power networks - preparing for an extreme event

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"Space Weather" is a generic term for how the changing space environment impacts our technological systems. It is most commonly used around solar disturbances which trigger changes in and around the Earth and can pose a hazard. One significant risk from space weather is through shocks in the solar wind compressing the Earth's magnetic field, leading to rapid changes in the horizontal magnetic field at the Earth's surface. This changing magnetic field produces a geoelectric field at the surface of the Earth, which poses a hazard for large conducting structures set up across the ground - examples being electricity transmission systems and gas pipelines in which "geomagnetically induced currents" (GIC) will flow. An extreme geomagnetic disturbance is likely to produce a collapse of the electrical power grid with damage to the infrastructure and loss of service. A reliable electricity supply is the lifeblood of any modern nation. A report from UN Committee on the Peaceful Uses of Outer Space [1] noted that "The largest potential socioeconomic impacts arise from space weather driven geomagnetically induced currents in electrical power networks".

In the last 1-2 decades, there has been growing evidence of Geomagnetically Induced Current (GIC) impacts at low and mid-latitudes, including the United Kingdom, South Africa, New Zealand, Brazil, China, and Japan (high latitude impacts have been widely accepted for decades longer). These impacts have occurred during "large" space weather events, which are expected to be at least an order of magnitude smaller than those for an extreme storm (for example the Carrington event of 1859, the 1921 storm, or the near miss of 2012). Fundamentally, the space weather risk to power systems comes from the interactions between a magnetoactive plasma, the Earth's magnetic field & ionosphere, the conducting Earth, and large conducting structures. Aspects of the problem are quasi-DC (the variation of GIC is typically slow enough to be treated as DC), but the problem is clearly highly electromagnetic involving the coupled Sun-Earth system spanning pure science through to highly applied engineering. URSI research already involves many varied space weather topics and hazards, although risks to energy transmission infrastructure have not been a strong focus for URSI to date.

In this presentation I will discuss this space weather hazard, and our efforts to better quantify associated risks and develop mitigation strategies. Space weather is a global hazard, but the risks are local; they depend on the region, national technological systems and the local ground conditions - this is an area where research is needed on a cascading series of scales, from global to local. Aspects of my presentation will be based on work undertaken inside the New Zealand Solar Tsunamis research programme (Figure 1), an international collaboration aimed at better understanding the impact and potential mitigation of extreme space weather on energy supply networks.

Figure 1. Logo for the Solar Tsunamis programme, funded by the New Zealand government.

References

[1] United Nations Committee on the Peaceful Uses of Outer Space Expert Group on Space Weather. (2017). Report on Thematic Priority 4: International Framework for Space Weather Services for UNISPACE+50. www.unoosa.org/oosa/oosadoc/data/documents/2018/aac.105/aac.1051171_0.html