Recent Geophysical Research

IDENTIFIES NORTH DAKOTA ELECTRICAL TRANSMISSION GRID AT RISK FROM POTENTIAL GEOMAGNETIC STORMS

Aurora Borealis as seen northeast of Linton in March 2023 (Moxness, NDGS)

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Space weather phenomena such as geomagnetic storms have recently been shown to be potentially hazardous to the electrical infrastructure in the upper Midwest, particularly in eastern North Dakota and western Minnesota (fig. 1). Researchers with the U.S. Geological Survey's Geomagnetics Program in Boulder, Colorado completed a study in which it was shown that the electrical transmission grid in North Dakota (and neighboring Minnesota) could be highly susceptible to a geomagnetic storm of a scale anticipated to occur about once per century (Lucas et al., 2019). The study used data collected from ground-based geomagnetic monitoring stations and magnetotelluric sounding stations that were placed across the U.S., and in North Dakota in 2017-18 (fig. 2), as a part of the National Science Foundation's Earth Scope Program (Anderson, 2018).

The shallow depths and lithology of eastern North Dakota's crystalline basement rocks are more resistive to geomagnetically induced currents since they occur at shallower depths and are dominantly silica-rich lithologies of igneous and metamorphic origin. This makes the overlying electrical grid more susceptible to electrical current propagation from the geomagnetically induced currents

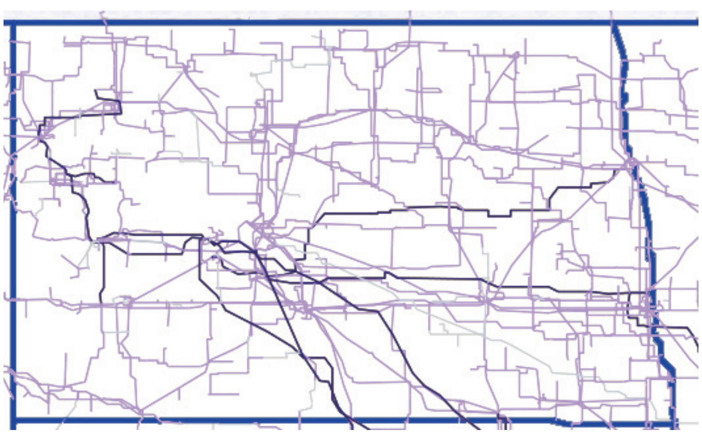

FIGURE 1.
The electrical transmission grid in North Dakota and western Minnesota (U.S. Energy Information Administration data, 2023). The darker lines are the larger 345 kV bulk electrical transmission lines. The grid is dense in central and eastern North Dakota.

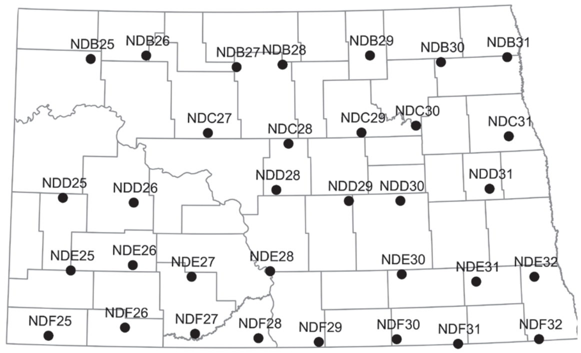

FIGURE 2.
Locations of NSF-EarthScope Magnetotelluric Array Sounding Stations in North Dakota that operated from Sept. 2017 to Sept. 2018. These stations were used to passively collect geophysical data on the geoelectrical properties of Earth created from space weather phenomena such as geomagnetic storms.

through the existing transmission lines since it is more difficult for the earth to absorb at these locations. Recent investigations by the USGS (Lucas, et. al, 2019) and modeling products created by NOAA's Space Weather Prediction Center (NOAA-SWPC, 2023) demonstrate this relationship (fig. 3). Plans and designs for new transmission lines in eastern North Dakota should take these factors into account.

Coronal mass ejections are created when the exceptionally strong magnetic fields on the sun abruptly realign and eject enormous amounts of solar material along with an accompanying strong magnetic field away from the sun. The coronal mass ejections become problematic when they travel along an intercept course with Earth's orbit.

These coronal mass ejections travel exceptionally fast from the sun to Earth and can arrive in just a few days traveling at a velocity of around 6.7 million miles per hour, which is about 1/100th of the speed of light. The solar wind is also buffeting Earth's magnetic field flowing past Earth at up to a million miles per hour (fig. 4).

We are approaching the next solar maximum in our current solar cycle, Solar Cycle 25, which is most likely to occur during the summer of 2025 (NASA, 2021). Updates from the NOAA SWPC reviewed during this writing forecast an even earlier arrival of the solar maximum in the summer of 2024! Although the anticipated solar maximum is estimated to be similar to the previous cycle and not significantly greater than average, the hazard from geomagnetic disturbances to the power grid remains a possibility.

When coronal mass ejections collide with the magnetic field of Earth they create geomagnetically induced currents that travel down the magnetic field lines and into Earth. These geomagnetically induced currents can travel along power lines and pipelines, creating overloads in the power grid and causing damages to transformers, resulting in large scale power blackouts. One of the more famous historical space weather events was the Carrington Event (named after Richard Carrington, an amateur sky observer in Redhill, England) which occurred in September of 1859 and set telegraph lines afire and resulted in an aurora seen around the world (Dobrijeciv and May, 2022). The Carrington Solar Storm is considered the largest on record. It is estimated that a Carrington-scale event occurring in today's electrified world would result in damages in the trillions of dollars.

At the time of this writing, the U.S. Energy Department's Grid Resilience State and Tribal Formula Grants program has awarded 7.5 million dollars to the state of North Dakota to upgrade the power grid and make it more resilient and reliable against extreme weather and natural hazards (Nicholson, 2023). Also, the North Dakota Department of Emergency Services and other supporting state agencies, including the NDGS, are currently updating the State's All Hazard Mitigation Plan. The plan includes the evaluation, planning, and mitigation of potential Space Weather Hazards.

With mitigation in mind, perhaps the construction of a new geomagnetic observatory station in North Dakota (fig. 5) would enhance the current capabilities of the existing array to collect important geomagnetic observations. This would support accurate analysis of the effects of these types of geophysical phenomena, in a current data sparse, but dense and susceptible region of electrical transmission capacity in the upper-Midwest.

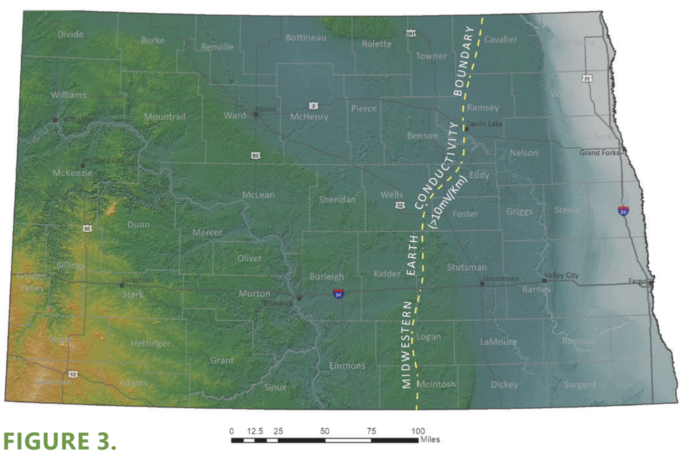

FIGURE 3.
Geophysical investigation and modeling by the USGS and NOAA's Space Weather Prediction Center show that eastern North Dakota has a higher susceptibility to geomagnetically induced currents. This is due to the shallower depth of more electrically resistant rocks in the eastern part of the state as opposed to the west.

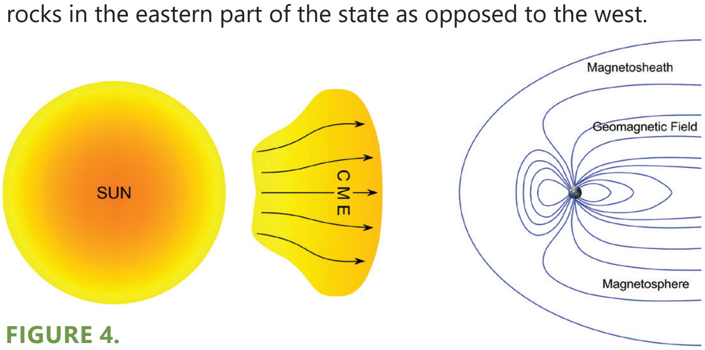

FIGURE 4.
Illustration of the relationships of the sun's influence on Earth's magnetic field.

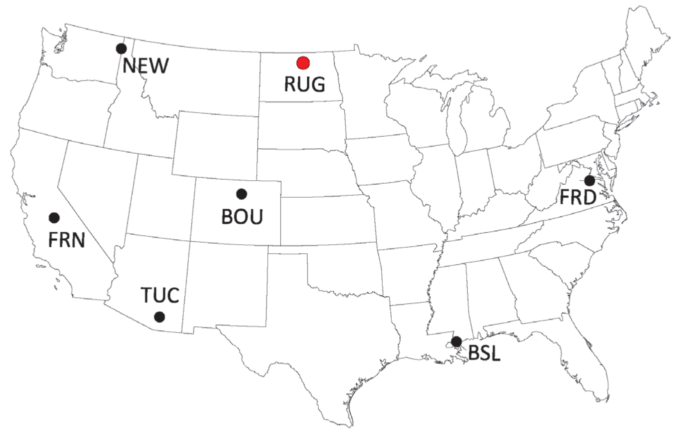

FIGURE 5.
Location of current geomagnetic observatory stations operated by the U.S. Geological Survey in the conterminous U.S. A new station in the upper Midwest, at Rugby, ND (RUG), could provide better geomagnetic field monitoring and increase the accuracy of regional geoelectrical hazard assessments. Current stations include Fresno, California (FRN), Newport, Washington (NEW), Tucson, Arizona (TUC), Boulder, Colorado (BOU), Stennis, Alabama (BSL), and Fredericksburg, Virginia (FRD).

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