Geomagnetic Storms and the Possible Effects on the Railroad System

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ABSTRACT
Geomagnetic storms are the result of the interaction of solar mass ejections with the earth’s magnetic field. They can place reliability risk upon expansive metallic ground based systems located in the upper latitudes, such as electrical transmission grids, pipelines, communication circuits and railroads. Communication satellites may also be exposed to a risk of damage or upset as a result of this solar phenomenon. With the advent of solar cycle #23, and a likely solar activity peak in 2000, this paper will provide a technical overview of the geomagnetic storm, a brief history of past events, possible effects upon railroad signal and communications systems, and a discussion concerning activities which should be considered to safeguard railroad operations.
INTRODUCTION

Geomagnetic Storms occur when the Earth is subjected to strong solar wind, resulting from a violent explosion on the sun called a coronal mass ejection (CME). Geomagnetic storms may distort the lines of force of the earth’s magnetosphere, (the magnetic lines of force projecting into space), and induce large voltages on long conductors on or near the surface.

A CME is an explosion of matter that is torn away from the surface of the sun and hurled into the solar system. These ejections, which are believed to occur due to strong magnetic fields interacting, may reach 10 billion metric tons in mass, with some of this highly charged matter incident upon earth’s magnetic field.

NASA and NOAA monitor several types of solar events that can have an impact on earth. CMEs, solar flares, prominences or filaments, and sunspots are several of these events. Sunspots are cooler areas in the corona where it is believed magnetic fields minimize energy from entering the gasses in this area. During a solar flare these magnetic fields release large quantities of energy with electrons and positive ions accelerating close to the speed of light.

The frequency of solar flares and CMEs tends to follow the eleven-year solar sunspot cycle. However, this does not rule out the possibility of a CME occurring in the solar cycle minima.

Effects

X-ray radiation of solar flares can strip electrons from atoms and molecules in Earth’s atmosphere. This changes the electrical characteristics of the upper atmosphere. It can effect radio communications in certain bands (HF) and cause the atmosphere to expand causing drag on
low orbiting satellites. It may also pose a health risk hazard to humans onboard high altitude aircraft traveling at upper latitudes.

The charged particles from CMEs can cause the aurora borealis, or northern lights, to appear at lower latitudes. This phenomenon is a result of the increase in energy from these charged particles causing the molecules and atoms in the atmosphere to be raised to higher energy levels and glowing as energy is released. Certain radio communications can be disturbed as a result of the aurora.

Energetic particles released from the sun can reach and distort the Earth’s magnetic fields and cause current to flow in the upper atmosphere. This electrojet current flows approximately 100km above the Earth. It can magnetically couple to the earth. Its fields create electric fields that can generate measurable Geomagnetically Induced Currents (GIC) to flow in the earth and in electrical conductors of long lengths. Power lines, communication lines, and pipelines may experience the effects of these induced currents. These currents change slowly over a period of minutes to hours and may saturate power transformers for half of the 60-hertz cycle. This can lead to harmonics on the line and eddy currents in the transformer resulting in transformer heating. Protective relays on power lines may trip when they should not, resulting in stability problems for the power line as well.

**History –**

Noticeable effects on the Earth were probably limited to observations of the Northern lights until the electric telegraph and transoceanic communication cables were installed. Both of these means of communications relied on long lengths of electrical conductors to pass information from point to point. On March 19, 1847 Barlow observed, “…strong alternating deflections on
his instruments. Similar effects were observed also on the telegraphs on several other lines of the railway.” (Barlow, 1849)

In the time period of August 28 to September 2, 1859, Mr. O.S. Wood Superintendent of the Canadian telegraph lines also reported that “…so completely were the wires under the influence of the aurora borealis, that it was found utterly impossible to communicate between the telegraph stations, and the line was closed for the night.” (Prescott, 1866)

Induced currents also caused noticeable disturbances in the transoceanic cables during periods of high solar activity. In 1957 voltage potentials of 3000 volts were recorded on such a cable between Newfoundland and Ireland.

Several recorded problems have occurred since these early observations including events on March 24, 1940, February 11, 1958, August 4, 1972, and the blackout of Quebec on March 13, 1989.

On March 13, 1989 during the peak of solar cycle #22 a severe geomagnetic storm occurred. The province of Quebec experienced a widespread power loss when a 735KV transmission line loaded at approximately 21,350MW suffered a loss of nearly one half of the line capacity due to the effects of the geomagnetic induced voltage and current on the line. This failure resulted in a chain reaction of similar failures over a wide geographical area, resulting in a total failure of the Quebec power grid. Additionally, a large step up transformer at the Tom’s River New Jersey generating station was also damaged by the geomagnetic currents that same day. Furthermore, several power interruptions were recorded in several other locations in North America, extending as far south as southern California.
Satellites have also been affected when large solar winds have compressed the magnetosphere from its normal distance of approximately 10 Earth radii to about 4 Earth radii placing the geostationary satellites outside the protection of the magnetic field. If this occurs, high-speed particles can cause corrosive effects on the satellite and spacecraft charging can cause discharges across components. Low earth orbiting satellites can also be affected because they have a limited amount of fuel to keep them in orbit. When solar storms expand the upper atmosphere by heating it, additional drag occurs on these satellites causing changes to their orbits. Additional fuel is then required to correct the orbit. Eventually when the fuel is exhausted they will fall to the Earth, as was the case for Skylab.

**RAILROADS SUSCEPTIBILITY**

With the migration to more sensitive electronics within the railroad industry, and the necessity and reliance upon RF communications, CSXT became interested in the Geomagnetic phenomenon to gain confidence that existing and new technologies were suitably robust to withstand the expected environment.

**Communications**

Generally the changes to the Earth’s ionosphere will affect radio transmissions in the high frequency band, (HF), because they use the ionosphere to reflect the radio wave back to earth. CSXT utilizes 160MHz (voice-VHF) and 900MHz (data - UHF) radios which should see little or no interruption due to these events. Satellites have been improved over the years to minimize risk of damage due to surface charging. The signal to communicate with the satellite through a highly charged layer of atmosphere during a storm can be attenuated. CSXT does not rely on
satellite communications for vital railroad functions. Fiber Optic long distance cables should also minimize effects to the leased network services for code lines and data and voice networks.

**Pole line** – Signaling circuits such as HD’s are balanced and intentionally ungrounded. Therefore, the only effect line circuits of this nature would see would be a common mode change, which should not result in any disturbance to the system.

**Commercial power** – This is the only area where some risk of outages to CSXT may exist. The effects of geomagnetic induced currents are most notable where the resistivity of the earth is high and along coastal areas. Several areas along CSXT, especially the Northeast US, are susceptible to these effects. As mentioned above under recent history Quebec Canada sustained a blackout in 1989. Electric fields generated by geomagnetic storms can result in currents flowing in the utility lines and transformers. If the storm was quite severe the utility would need to react within seconds to mitigate the problem by shortening line lengths, insuring adequate MVARS are available, or take other measures to be sure protective equipment does not interrupt the system when it should not.

Many utilities are taking proactive measures to monitor temperature of the oil in transformers as well as, monitoring harmonic content of their power grids to know when changes are occurring. The Electric Power Research Institute is currently running a program known as SUNBURST to monitor changing conditions that can be accessed by other member utilities to see how changes are occurring. Not all power utilities are participating members in this project and not all are taking the same steps. A software tool is available to predict approaching storms based on the early warning of the ACE satellite, but few utilities in the world are presently using this. There is
however a certain amount of risk to the grids that supply power to North America should a large storm should occur.

**RAILROAD MITIGATION**

Major facilities, especially in areas prone to geomagnetic induced currents, should be evaluated for backup power arrangements to minimize down time in the event of a commercial power system failure. A typical emergency action plan used for hurricanes, floods, and tornadoes that specifies where generators and other equipment are located would serve this function. Key areas need to be identified in advance so a plan of action can be executed should such an emergency arise.
WORKS CITED


