Australian Government
Bureau of Meteorology

Overview of space weather and potential impacts and mitigation for the energy and resource sector

A severe space weather event can disrupt electrical currents in power lines, increase radiation in the atmosphere, disrupt communication and navigation, damage satellites and risk human health. Impacts for the energy and resources sector can be serious. Response and mitigation planning is necessary.

Key points

- Space weather has a direct impact on the assets and operations of industries within the energy and resource sector. These include power networks, long resource pipelines, mineral exploration surveys, and the operations of the offshore oil and gas industry.
- Space weather can create rapid variations of the Earth's magnetic field, often referred to as geomagnetic storms. These variations cause currents to flow in power networks and long resource pipelines. This may lead to asset damage in power systems and increased corrosion in pipelines. The magnetic field variations also disrupt or compromise mineral exploration surveys and cause targeting errors in directional drilling for offshore resources.
- Space weather can impact operations through the sector's increasing reliance on satellite communications and precision navigation and timing systems. These may be compromised by space weather.
- Severe space weather can compromise power system operations and assets by injecting unwanted current through the grounding points of high-voltage transformers. These currents offset the operations of transformers from their optimum range and can lead to:
  - voltage instability, tripping of voltage support systems and other system components
  - increased reactive power, leading to inefficient power transfer
  - heating and transformer damage, transformer failure
  - in extreme cases, system collapse.
- The Bureau continues to work with industry to help mitigate the impacts of space weather on the sector and protect Australia's electricity network from severe space weather events.

What causes space weather?

The main driver of space weather is the Sun. Solar activity and the resulting space weather vary day-to-day, seasonally, and over multi-year cycles. Irregular solar activity, including explosive eruptions called solar flares and coronal mass ejections (CMEs), can have a significant impact on the near-Earth space environment.

Major solar flares can be associated with an increase in:

- x-ray and radio emissions that reach Earth within 8 minutes
- energetic protons, reaching the Earth in 20 minutes to 6 hours.

During a CME, billions of tonnes of magnetised solar plasma erupt into space at up to 3000 km/s, with solar wind particles and magnetic field strength, typically reaching Earth within half a day to 3 days. If the material is directed towards the Earth, geomagnetic, ionospheric and radiation storms can occur.

Severe space weather can significantly impact the technologies we rely on in different ways and over different time scales.

How does space weather affect the energy and resource industry?

Space weather can cause relatively short-term variations of the Earth's magnetic field. This is called a geomagnetic storm. They result in electric fields in the Earth's surface that can drive currents through long grounded conductors such as power grids and pipeline networks. The currents are called geomagnetically induced currents or GICs. GICs can cause asset damage and operational issues.

Short term geomagnetic field variations can also disrupt exploration surveys for valuable mineral and resource targets.

Geomagnetic storms and other space weather phenomena can lead to disrupted or unreliable satellite communications, and precision navigation and timing systems. The power, exploration, oil and gas industries are becoming increasingly reliant on these systems for their operations.

Power networks

Geomagnetic storms produce GICs that can flow through high-voltage power transformers and cause them to operate outside their optimum performance range, resulting in overheating and possible failure, system harmonics, unwanted power consumption and instability in the power systems. Under extreme conditions, power restrictions, outages or system collapse may occur.

EXAMPLE: GEOMAGNETIC STORM CAUSES POWER OUTAGE TO 6 MILLION

The geomagnetic storm of 12–13 March 1989 caused damage to the Hydro-Quebec power network. This resulted in loss of power to 6 million people for 9 hours. The same event produced numerous power network anomalies across the United States, United Kingdom, and Europe, including failure of high-voltage transformers.

High-voltage transformers are designed to efficiently transfer power for alternating current (AC) and voltage signals. GICs are slowly varying and essentially appear as direct current (DC) offsets in the system. This can shift the operating range of the transformer into a highly non-linear operating environment referred to as the 'saturation region'. This situation is referred to as 'transformer half-cycle saturation' and leads to asymmetric waveforms that result in multiple operating challenges for the power system. These include system harmonics, relay tripping, inefficient power transfer, and transformer overheating.

Failure of system components may occur at geomagnetic storm onset, during the storm, or in the ensuing weeks and months. Continued exposure to elevated GICs can lead to a decline in the integrity of power system transformers. This is typically indicated by dissolved-gas analysis (DGA) measurements. DGA measurements highlight the existence of by-products in the transformer cooling oil related to the deterioration of insulation between high-voltage transformer windings from overheating. Sustained exposure to low-level geomagnetic storm activity may also lead to eventual failure of critical system components.

EXAMPLE: CORONAL MASS EJECTION AFFECTS POWER IN NEW ZEALAND

On 6 November 2001, a fast-moving CME impacted the Earth's magnetic field outer boundary, compressing it rapidly. The response was a rapid change in the magnetic field at the Earth's surface over low–middle latitude regions. Almost simultaneously, components of New Zealand's South Island power system tripped offline. This included a high-voltage transformer which failed within an hour of being returned to service. New Zealand's transmission network service provider subsequently approved the installation of further GIC monitors in parts of the network.

EXAMPLE: SEVERE SPACE WEATHER DAMAGES POWER NETWORK IN SOUTH AFRICA

The months of October–November 2003 were a particularly active period for space weather. Over the ensuing weeks and months, the integrity of multiple transformers in the South African power network continued to decline after the space weather activity subsided. Dissolved-gas analysis results from these transformers showed a dramatic increase in the by-products that result from overheating of the transformer winding insulation. This overheating was attributed to the severe space weather.

Resource pipelines

Long steel pipelines that carry essential resources are prone to corrosion and use protection systems to inhibit damage. GICs produced during geomagnetic storms can interfere with these protection systems, causing an increased rate of corrosion and reducing asset lifespan.

Australian standards mandate that long steel pipelines must maintain an electric potential of between -0.8 to -2.0 volts with respect to the surrounding soil for 90% of the time, to inhibit corrosion and ensure pipeline integrity and safety. This potential is maintained using cathodic protection systems attached at selected locations along the pipeline. The capacity of some of these systems changes in response to GICs. Ineffective design or inadequate distribution of cathodic protection systems can lead to insufficient protection along the full extent of the pipeline.

Asset owners are required to regularly survey pipelines along their extent to demonstrate the cathodic protection systems are adequate to maintain structural integrity. GICs can be a significant source of noise to these routine surveys, compromising survey results and providing interpretation challenges.

Mineral exploration

One method used by the exploration industry to delineate buried targets of potential economic importance is magnetic surveying. Geomagnetic storms present problems when interpreting and performing ground and airborne magnetic surveys and can lead to surveys being postponed or disrupted.

Magnetic susceptibility is a measure of a material's ability to be magnetised. Magnetic surveys identify minerals in the Earth's crust through their magnetic susceptibility signatures. Different minerals have different susceptibility. Magnetic surveys typically measure a total field signature which includes the Earth's main field or background field, crustal field signatures, regular daily variations and irregular variations due to space weather. The background field is typically removed using measurements at a nearby base station.

For airborne magnetic surveys covering large areas, the daily regular variations are removed using different techniques, including 'tie-line' leveling. This involves carrying out the survey in a grid-style flight pattern and using the measured difference at intersection points to estimate the error curve for the regular variations.

Rapid variations of the magnetic field due to space weather may occur between intersection points and therefore not be adequately removed. These rapid variations may have similar spatial signatures to those used to identify petroleum deposits during survey interpretation. Magnetic surveys are often postponed or disrupted during significant space weather.

Oil and gas

Space weather can interfere with the drilling operations of the offshore oil and gas industry. Due to reception issues at ocean depths, modern navigation systems can't be used and drilling operations navigate using the Earth's horizontal magnetic field. Significant space weather can modify this field by several degrees depending on location. This causes costly errors when locating anticipated drilling wells.

Space weather can further impact the offshore oil and gas industry through their increasing reliance on satellite communications, and precision navigation and timing systems. Large positioning errors in these systems due to space weather can result in unexpected movements of floating drill platforms. This may endanger the safety of workers.

EXAMPLE: SATELLITE OUTAGE AFFECTS TASMANIAN NATURAL GAS PIPELINE CONSTRUCTION

During the construction of a Tasmanian natural gas pipeline commissioned in 2002, there was a 2-hour outage in satellite positioning services. This caused significant operational issues. Adverse space weather had not been planned for.

Cross-sectoral impacts

Extreme space weather events pose a significant threat to the energy and resource sector because of its dependency on satellite-based communications and precise positioning and timing systems. These are vulnerable to space weather.

Many critical infrastructure sectors also have significant dependencies on services provided by the energy and resource sector. Extreme space weather has the potential to simultaneously directly, and indirectly, impact all critical infrastructure sectors.

Response to a severe space weather event

Like any severe weather, it is critical to plan and prepare for a severe space weather event. The Bureau provides prediction and real-time information about space weather, enabling industry to take protective action and prepare for disruptions.

We work closely with the energy and resource industry to limit their risks including delivery of:

- space weather forecasts, warning and alerts
- information specific to the energy and resource sector – such as metrics that quantify GIC activity and estimates of the flow of GIC in the National Electricity Market, for situational awareness
- consultancy and training.

The Australian Energy Market Operator (AEMO) has implemented response procedures for the National Electricity Market for the management of geomagnetic storms. They are invoked in response to our Severe Space Weather Warning service.

In response to Bureau forecasts, warnings and alerts, the resource pipeline industry may increase the capacity of corrosion protection equipment or suspend surveys of pipeline protection systems. Ground and airborne exploration surveys may be postponed, and offshore oil and gas drilling operations may be suspended to mitigate safety risks.

Longer-term mitigation measures

Understanding and mitigating the space weather risk also means designing and managing processes and systems differently. To ensure energy and resource operations become more resilient in future, the Bureau:

- continue to conduct risk assessments to obtain a comprehensive understanding of the direct impacts of space weather on the various industries within this sector and subsequent indirect impacts due to dependencies across other sectors
- continue to practice under the Australian Government Crisis Management Framework to respond to space weather events that coordinates Australia's response to severe space weather across relevant departments, agencies and industry informed by appropriate risk assessment findings
- collaborate with industry, government, and academia to develop and improve models and forecast capabilities, validated with expanded industry observations, that enhance industry's ability to adequately mitigate severe space weather with minimum disruption to society.

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