Australian Government
Bureau of Meteorology

Space weather and 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 systems, damage satellites and pose health risks. Impacts for the energy and resources sector can be serious, and response and mitigation planning is necessary.

Key points

- Space weather has a direct impact on assets and operations in 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, called 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. Variations in the magnetic field can also disrupt or compromise mineral exploration surveys and cause targeting errors in directional drilling for offshore resources.
- Space weather can impact the satellite communications and precision navigation and timing systems that the sector increasingly relies on.
- 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, and tripping of voltage support systems and other system components
  - increased reactive power, leading to inefficient power transfer
  - heating and transformer damage, or 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, which reach Earth within 8 minutes
- energetic protons, which reach the Earth in 20 minutes to 6 hours.

During a CME, billions of tonnes of magnetised solar plasma erupt into space at up to 3,000 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 create rapid variations of the Earth's magnetic field. This is called a geomagnetic storm. These 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 disrupt satellite communications, and can affect position, 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, causing them to operate outside their optimum performance range. This can result in overheating and possible failure, system harmonics, unwanted power consumption and system instability. Under extreme conditions, power restrictions, outages or system collapse may occur. High-voltage transformers are designed to efficiently transfer power for alternating current (AC) and voltage signals.

Example: Geomagnetic storm causes power outage for 6 million people

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.

GICs vary slowly and 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.

Example: Coronal mass ejection affects power in New Zealand

On 6 November 2001, a fast-moving CME impacted the outer boundary of the Earth's magnetic field, 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.

Failure of system components can occur at the onset or during a geomagnetic storm, or in the weeks and months that follow. 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 which are related to the overheating and deterioration of insulation between high-voltage transformer windings. Sustained exposure to low-level geomagnetic storm activity may also lead to eventual failure of critical system components.

Example: Severe space weather damages power network in South Africa

The months of October–November 2003 were a particularly active period for space weather. In the weeks and months that followed, even as the space weather activity subsided, the integrity of multiple transformers in the South African power network continued to decline. Dissolved-gas analysis results from these transformers showed a dramatic increase in the by-products that result from overheating of the transformer winding insultation. 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 that the cathodic protection systems are adequate for maintaining their structural integrity. GICs can be a significant source of noise to these routine surveys, compromising survey results and providing interpretation challenges.

Mineral exploration

Magnetic surveying is one method used by the exploration industry to delineate buried targets of potential economic importance. Geomagnetic storms can disrupt the interpretation and performance of ground and airborne magnetic surveys.

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.

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.

Space weather can further impact the offshore oil and gas industry through its increasing reliance on satellite communications and position, navigation and timing systems. Large positioning errors in these systems caused by space weather can result in unexpected movement of floating drill platforms, which can endanger the safety of workers.

Cross-sectoral impacts

Extreme space weather events pose a significant threat to the energy and resource sector due to its dependence on satellite-based communications and position, navigation and timing systems which 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 impact all critical infrastructure sectors, directly and indirectly.

Response to a severe space weather event

As with severe terrestrial weather, it is critical to plan and prepare for severe space weather events. The Bureau provides prediction and real-time information about space weather, which can assist industry to make decisions about protective action and prepare for disruptions.

We work closely with the energy and resource industry to help mitigate the risks of space weather impacts by delivering:

- 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
- space weather education.

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

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

Longer-term mitigation measures

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

- contributes to space weather risk assessments for a comprehensive understanding of the direct and indirect impacts of space weather on the sector, along with dependencies across other sectors
- supports the coordination of Australia's response to severe space weather across relevant departments, agencies and industry, informed by appropriate risk assessment findings
- collaborates with industry, government, and academia to develop and improve models and forecast capabilities. This is validated with expanded industry observations that enhance industry ability to mitigate risks of severe space weather impacts on the community.

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