Space Weather effects during the 2024 Mother's Day magnetic storm in Uruguay

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Abstract

The Mother's Day magnetic storm on May 10–14, 2024, was the most intense space weather event in twenty years. The event triggered auroras that were seen at several low-latitude locations around the world. Thus, we present some optical observations registered by local observers along the south coast of Uruguay. These are the first documented aurora sightings in Uruguay at 34^o S in latitude. Additionally, we present geomagnetically induced currents (GIC), estimates in the 500 kV Uruguayan power grid during the event. The GIC estimates suggest peak values of $\gtrsim$ 20 A at some substations. These estimates were compared with direct observations made at a low-latitude HV substation located close to Veracruz, Mexico. The comparison suggests that, despite their differences, similar amplitudes can be expected in the Uruguayan power grid at 34^o S. Furthermore, the comparison suggests that GIC can potentially threaten the integrity of low-latitude power grids, including those in South America.

Introduction

On May 8-9, 2024, the Sun's active region AR3664 emitted a series of strong solar flares which originated a train of Coronal Mass Ejections (CME). These CMEs hit the Earth's magnetosphere on May 10-11, originating the most intense space weather event since October 29, 2003, Halloween storm. The magnetic storm triggered red auroras that were seen at several low-latitude locations around the world and a series of disturbances in GPS systems, satellite operations and air traffic control [1]. The figures below show red aurora observations captured by local observers along the southern coast of Uruguay during the night of May 10–11, 2024. This was an invaluable example of community science that helped assess the phenomenon's timing and geographical extension. These observations are the first documented aurora sightings in Uruguay. Besides this, in the following sections, we show GIC estimates calculated for the 500 kV Uruguayan power grid during this event. The comparisons suggest that the GIC phenomenon can pose a potential threat to the integrity of low-latitude power grids, including those in Latin America.

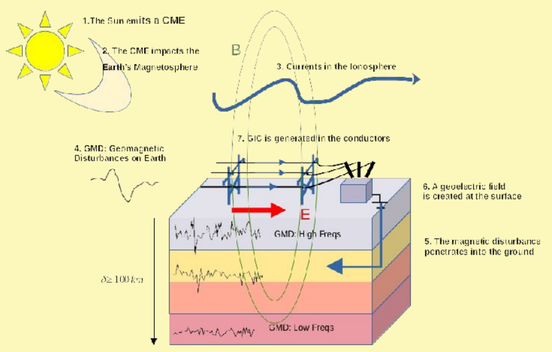
Ciudad de la Costa (34.8^o S, 55.9^o W)
Image credit: Matias Mederos

Punta del Este (34.9^o S, 54.9^o W)
Image Credit: Mateo Boffano

Punta del Diablo (34.0^o S, 53.5^o W)
Image credits: Adriana Giglio

GIC Modeling in a Power Grid

The geomagnetically induced currents are the result of a chain of events that start in the Sun and impact on the grounded technological systems at the Earth's surface. Rapid time variations in the Earth's geomagnetic field, caused by CME impacts, create an induced geoelectric field on the ground (Faraday Effect). This E-field produce currents between earthed conducting infrastructures (e.g., transmission lines, pipelines) and the ground. In general, GIC intensities depend on a combination of geophysical and engineering factors, (i.e., network topology, geographical orientation, ground resistivity and conductor resistances). In this case, the GIC was calculated using the Nodal Admittance Method (Lehtinen-Pirjola, 1985) and the methodology details are shown in (Caraballo et al., 2016)[2]

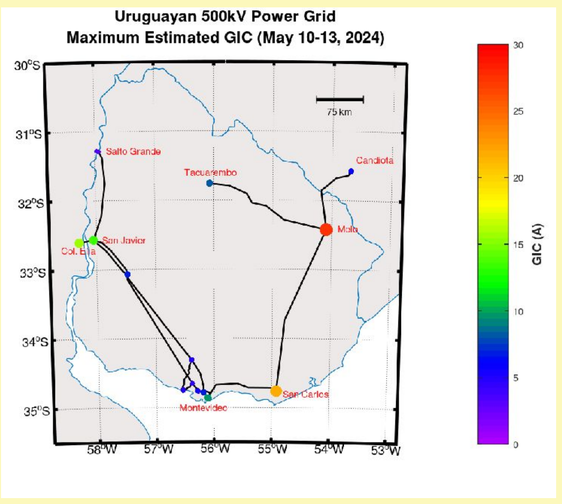


As occurred in Quebec on the March 13, 1989, great magnetic storm, the GIC can trigger reactive power consumption, relay tripping and ultimately, extended blackouts on HV power grids. Global socio-economic consequences of an extreme magnetic storm have not been not properly assessed yet. Therefore, the GIC can pose a new threat to the technological infrastructure at the Earth's surface.

Results and Discussion

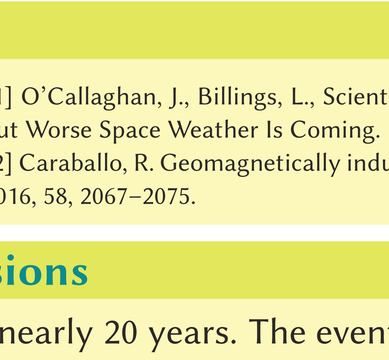
The Uruguayan Power Grid is composed of two subnetworks operating at 500 and 150 kV, respectively. The 500 kV grid is directly connected to the Argentinian system through Salto Grande and San Javier substations, and to the Brazilian grid through a frequency-converter substation at Melo.

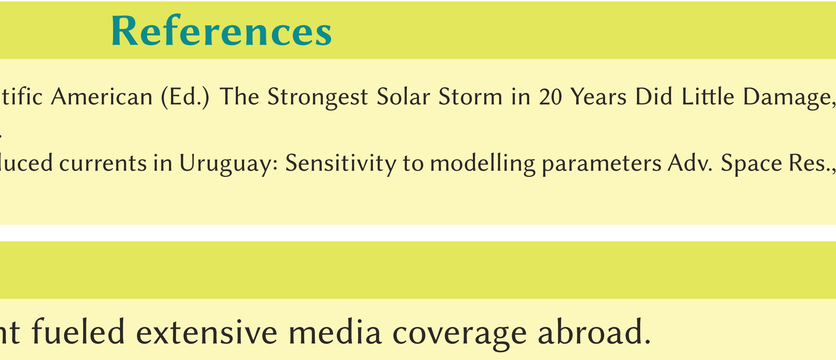
The 150 kV grid was not considered due to its high conductor resistances and short length of its branches. The figure shows the maximum estimated GIC at the 500 kV substations of the Uruguayan power grid on May 10-13, 2024. Noticeable intensities are shown in the San Javier-Col. Elia interconnection and in the San Carlos—Melo branch, which runs almost entirely over a high resistivity terrain. However, for substations connecting with the Argentinian and Brazilian power grids (Col. Elia, Candiota, Salto Grande) are expected to get significant errors because they are connected to other networks not considered in the model.



Estimated vs Observed GIC

In blue the estimated GIC at the most affected substations in the Uruguayan power grid (i.e., Melo (32.42^o S, 54.09^o W) and San Carlos (34.76^o N, 54.92^o W)), were compared with direct observations made at a low-latitude HV substation at Laguna Verde, Veracruz, Mexico,(19^o N, 96.4^o W), near the geomagnetic conjugate points (red).





(Left) Locations of Melo and Laguna Verde substations. In red, blue & green, the magnetic equator, latitudes and first magnetic meridian, respectively. (Right) GIC at San Carlos, Melo & Laguna Verde.

We can see that similar GIC amplitudes were observed during the main phase of the storm at the Laguna Verde substation. The bottom panel on the right shows δH, extrapolated for Uruguay, and the time interval where the most intense GIC occurred. Despite the differences, Mexican and Uruguayan power grids are both coastal. The Uruguayan power grid operates at higher voltage, with several branches located over higher resistivity terrains and directly connected to the Argentinian grid. These characteristics, may favor the developing of intense GIC in the Uruguayan case.

References

[1] O'Callaghan, J., Billings, L., Scientific American (Ed.) The Strongest Solar Storm in 20 Years Did Little Damage, but Worse Space Weather Is Coming.

[2] Caraballo, R. Geomagnetically induced currents in Uruguay: Sensitivity to modelling parameters Adv. Space Res., 2016, 58, 2067–2075.

Conclusions

- The May 20, 2024, magnetic storm was the most relevant space weather event in nearly 20 years. The event fueled extensive media coverage abroad.
- Red aurora was seen by $\sim$ 6 hrs in Uruguay. It were the first aurora sightings registered by local observers along the south coast. Such community contributions were collected by OGU and helped to estimate the extension and timing of the phenomena.
- GIC intensities $\gtrsim$ 20 *Amps* were estimated at some substations of the 500 kV Uruguayan power grid during the main phase of the storm. The comparison with actual observations made at a low-latitude substation in Mexico suggests that GIC can be a significant threat to power grids in South America.

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