Analysis of Geomagnetically Induced Currents over Continental United States

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Introduction

- An analysis of measured GIC data collected at mid-latitudes by U.S. power utilities under the EPRI Sunburst project is performed.
- The study includes a statistical investigation of all events and an overview of the top three highest GIC recordings in the data.
- We show that roughly 76% of the events are associated with the main phase of geomagnetic storms, while about 24% are associated with sudden storm commencement.
- It is also directly shown, for the first time, that mid-latitude positive bays (MPBs) can cause large GICs over the continental United States.

Data and Methodology

- The data presented in this study comprises of GIC measurements recorded at 17 EPRI SUNBURST transformer locations across the United States.
- The data covers the period from 2010 to 2021 and is limited to events for which GIC values greater than 10 A were recorded.
- Based on this event selection criterion, 52 geomagnetic storms with a recorded Kp > 6 are included in the analysis.
- We use magnetometer data to investigate geomagnetic variations during each of the storm events that have been identified.
- The list of geomagnetic observatory sites used in this study is displayed in Table 1.

Table 1. List of geomagnetic Observatories locations used in the analysis of the ground geomagnetic field response.

Name	Code	Operator	Latitude [Deg. North]	Longitude [Deg. West]
Boulder	BOU	USGS	40.14	254.76
Stennis Space Center	BSL	USGS	30.35	270.36
Federicksburg	FRD	USGS	38.21	282.63
Fresno	FRN	USGS	37.09	240.28
New Port	NEW	USGS	48.27	242.88
Ottawa	OTT	NRCan	45.40	284.44
Tucson	TUC	USGS	32.17	249.27

Results – Statistical Approach

- The analysis confirms that there is a good correlation between the number of geomagnetic storms per year and the number of recorded GIC events.
- About 76% of the top 17 GIC events are associated with the storm main phase, while only 24% are attributed to storm sudden commencements.

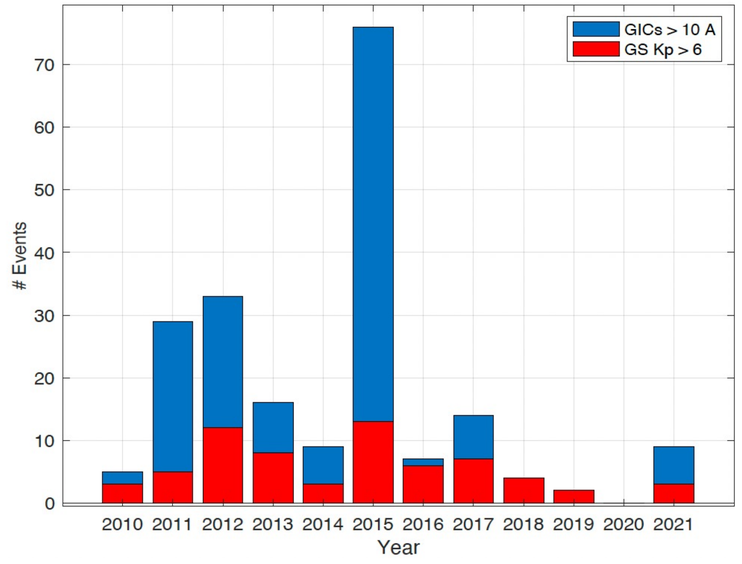

Figure 1: Summary of measured GIC events (blue) with current above 10 A across the United States during the period from 2010 to 2021. The red bars indicate the number of geomagnetic storms (GS) with Kp index greater than 6.

Table 2. Summary of the top 17 measured GIC event at different sites across the United States during the period from 2010 to 2022. The table also includes the associated geomagnetic storm information. The symbols represent: SSC - Sudden storm commencement, IP - Initial phase, and MP- Main phase.

Storm Date	Location	Max GIC [A]	Time of max GIC UT/LT [hh:mm]	Max Kp Index	Storm phase
09/26/2011	Site #1	24.7	19:36	6	MP
10/24/2011	Site #2	25.2	18:31	7	SSC
06/23/2015	Site #3	23.7	3:32	8	MP
09/09/2015	Site #4	52.6	11:01	6	MP
09/09/2015	Site #5	50.1	11:01	6	MP
06/23/2015	Site #6	22.2	3:32	8	MP
09/26/2011	Site #7	30.8	19:37	6	MP
09/08/2017	Site #8	17.8	1:34	8	MP
09/12/2014	Site #9	11.3	15:54	6	SSC
09/12/2014	Site #10	20.0	15:54	6	SSC
05/12/2021	Site #11	15.9	12:20	7	MP
06/22/2015	Site #12	12.1	18:33	8	SSC
09/12/2014	Site #13	20.2	22:54	6	MP
10/02/2013	Site #14	31.9	04:34	8	MP
03/17/2015	Site #15	11.6	13:50	8	MP
06/22/2015	Site #16	18.7	20:04	8	MP
05/12/2021	Site #17	10.3	12:19	7	MP

Results – Observations

- We picked out three events for further analysis, but only one is presented here.
- The event in Figure 2 directly shows, for the first time, that MPBs can cause large GICs over the continental United States

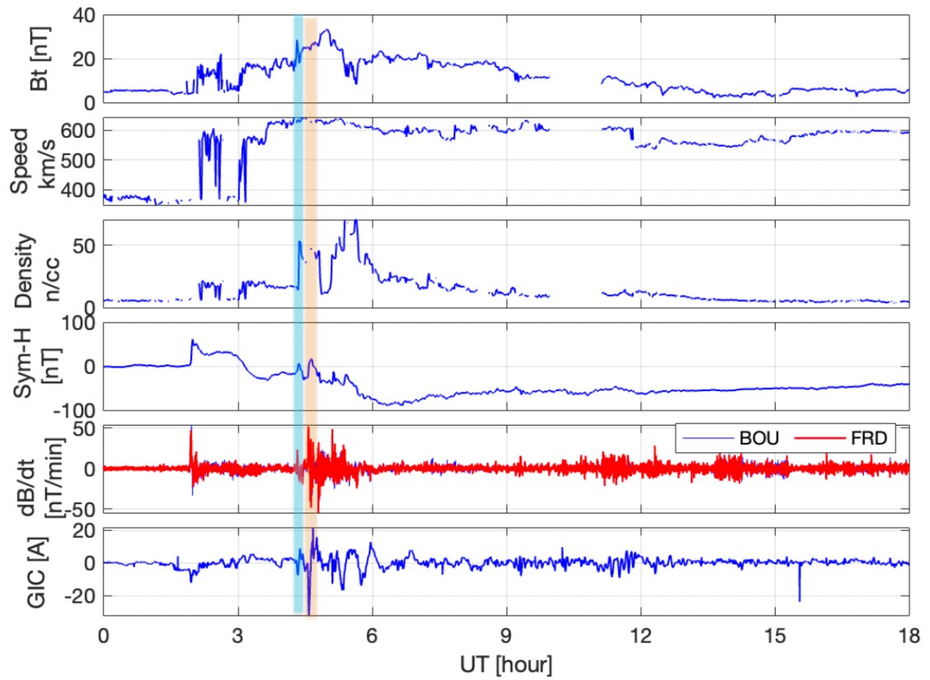

Figure 2: A response of the geomagnetic field and GICs during the CME on 10/02/2013. The top three panels display the IMF Bt, solar wind speed, and density, while the bottom three panels show the Sym-H index, dB/dt at BOU and FRN, and the recorded GIC at Site #14. The blue shaded area highlights a region of sudden IMF Bt and solar wind density enhancement, while the brown shaded region marks the GIC event.

Summary

- For the first time, we extensively investigate the occurrence of GICs greater than 10 A across the continental United States using measured GIC data from the EPRI SUNBURST project along with geomagnetic data from USGS and NRCan Observatory stations.
- Substorm-driven MPBs can cause large GICs at U.S. locations.
- Some GIC events are not well correlated with dB/dt variations, therefore, a more details analysis of individual GIC events is suggested for a better understanding of their production and the coupling of space weather to the power grid.

Acknowledgements

This work was funded via the NASA SWO2R Program Grant award 80NSSC20K1364.

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