Tutorial Title

The impact of Geomagnetically Induced Currents on Power Quality

Speakers

Speaker 1	Name	Dr.-Ing. Roger Alves de Oliveira
	Affiliation	Technical University of Eindhoven
	Webpage/CV link/short bio	https://research.tue.nl/en/persons/roger-alves-de-oliveira/ Roger Alves de Oliveira earned his PhD in Electric Power Engineering from Luleå University of Technology (LTU), Sweden, in 2023. In 2024, he worked as a postdoctoral researcher and lecturer at LTU. He also worked in industry as a Power System Consultant, focusing on hydrogen integration into the grid, digitalisation for power quality, and grid code compliance of power converters. He is currently a postdoctoral researcher in Electrical Energy Systems at Eindhoven University of Technology (TU/e), the Netherlands, where he works on advanced harmonic analysis for renewable hydrogen systems. His research interests include power quality, harmonic distortion and voltage-dip assessment, fault ride-through of power plants, geomagnetically induced currents in power systems, and PQ data analytics using deep learning.

Speaker 2	Name	Dr.-Ing. Rafael de Souza Salles
	Affiliation	Lulea University of Technology
	Webpage/CV link/short bio	https://www.ltu.se/en/staff/r/rafael-de-souza-salles Rafael S. Salles (Member, IEEE) received the Ph.D. degree in electrical power engineering from Luleå University of Technology, Luleå, Sweden, in 2025. He is currently an Associate Senior Lecturer with the Electric Power Engineering Group, Luleå University of Technology. His research interests include power system harmonics, waveform distortion assessment, railway electrification, and power quality in general.

Speaker 3	Name	Professor Math Bollen
	Affiliation	Lulea University of Technology
	Webpage/CV link/short bio	https://www.ltu.se/en/staff/m/math-bollen

		Math H. J. Bollen (Fellow, IEEE) received the M.Sc. and Ph.D. degrees from the Eindhoven University of Technology, Eindhoven, The Netherlands, in 1985 and 1989, respectively. He is currently a Professor of Electric Power Engineering with Luleå University of Technology, Skellefteå, Sweden. Earlier he has, among others, been a Lecturer with the University of Manchester Institute of Science and Technology, Manchester, U.K., a Professor of Electric Power Systems with Chalmers University of Technology, Gothenburg, Sweden, an Research and Development Manager and Technical Manager power quality and distributed generation with STRI AB, Gothenburg, and Technical Expert with the Energy Markets Inspectorate, Eskilstuna, Sweden. He has authored and coauthored a few hundred papers, including a number of fundamental papers on voltage dip analysis, two textbooks on power quality, Understanding Power Quality Problems and Signal Processing of Power Quality Disturbances, and two textbooks on the future power system: Integration of Distributed Generation in the Power System and The Smart Grid: Adapting the Power System to New Challenges. He has defined voltage dips as a research subject, has spread the use of the term "hosting capacity," and has contributed to defining supraharmonics as a research area. He was a recipient of the CIGRE Study Committee Award.

Abstract

This tutorial introduces geomagnetically induced currents (GICs) from a power quality (PQ) point of view. It covers measurement results, monitoring methods based on measurements, geographic validation studies from research conducted by the speakers. The main goal of the tutorial is to explain what causes geomagnetic disturbances, how they affect power quality, and mainly on how to detect them from PQ measurements.

The tutorial begins by briefly explaining how GICs are originated during geomagnetic disturbances triggered by solar activity, such as coronal mass ejections. It describes how these currents travel through long transmission lines and flows to the transformer neutrals. This can cause half-cycle saturation, leading to harmonic distortion. Special attention is given to even harmonics, which are a better indicator of the impact of solar storm on the power grid that measurements of geomagnetically induced currents. Examples of measurements from high-voltage transmission systems in high-latitude locations will show that these harmonic patterns are affected by changes in the geomagnetic field, ground conductivity, and system loading/generation. The discussion

also covers the analysis beyond of propagation of GIC-related harmonic to medium- and low-voltage networks.

The tutorial also introduces a data-driven approach for large-scale monitoring using deep anomaly detection applied to long-term harmonic measurements. The approach enables screening of large historical datasets and supports situational awareness during geomagnetic disturbances.

The tutorial then expands the analysis beyond high-latitude transmission grids. It is presented a case study at the South Atlantic Anomaly (SAA), which is a region where significant GIC-related disturbances can occur at mid and low latitudes. The results of this analysis are cross-validation with space weather indicators and simultaneous observations in different geographic regions validation. Moreover, cases of protection misoperation at the analysis at a power system at SAA due to high harmonic content during GIC are presented.

This way, the tutorial provides a practical workflow for understand the PQ variations and events during geomagnetic disturbances.