Geomagnetically Induced Currents in Austria

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Geomagnetically Induced Currents (GIC)

Solar eruption, Coronal mass ejection (CME) → Cloud of energetic particles hits Earth’s magnetosphere

Enhanced electrojet and rapid variations seen in geomagnetic field

Credit: NASA
Geomagnetically Induced Currents (GIC)

Solar eruption, Coronal mass ejection

Enhanced electrojet and rapid variations seen in geomagnetic field

Credit: SPX Transformer Solutions
March 13th 1989

Quebec without power for 9 hours

Credit: PS&E
APG and GIC – why?

• Correlation between **large amounts of DC and geomagnetic activity** discovered by Austrian Power Grid, data from 2014:

• Investigations started because of unexpected **noise emissions** of transformers

• **DC currents** can be detected as source for noise emissions

• First studies with TU Graz show **significant correlation between GIC and DC currents** in Austrian Power Grid

Credit: APG
APG and GIC – why?

• Correlation between large amounts of DC and geomagnetic activity discovered by Austrian Power Grid, data from 2014:

• Studies are important for risk analysis of the impact of GIC
Why Austria?

- Levels of GIC expected to be similar to GIC in Scotland or lower Scandinavia (Denmark) due to **lower conductance** of Alps

Credit: Viljanen et al. (2014)
Conrad Observatory

- Geomagnetic observatory in Austria (INTERMAGNET WIC)
- In the limestone Alps

Credit:ZAMG/Lammerhuber
Basic Data

- \( \frac{dB}{dt} \) ... geomagnetic variations

- \( \rho(x, t) \) ... ground conductivity

- \( M_{\text{network}} \) ... power network topology
Basic Data

- **dB/dt** ... geomagnetic variations
  - Conrad Observatory
  - Assumed to be homogeneous

- **ρ(x, t)** ... ground conductivity
  - Cooperation with geological survey
  - 2D surface conductivity
  - 1D subsurface layer conductivity

- **\(M_{\text{network}}\)** ... power network topology

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Credit: GBA
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- $\mathbf{M}_{\text{network}}$ ... power network topology
  - Provided by power grid operators
  - Need all parameters
  - Includes surrounding countries

Credit: APG
Scenario: Strong geoelectric field

- Scenario: 1 V/km geoelectric field --> max. GIC = \(49.13\) A near Vienna
Scenario: Removal of station from grid

- Stations in 380 kV grid with greater distances to connecting nodes are most susceptible to large GIC
- → The same nodes cause large increases in GIC elsewhere when removed

- Generally, removing a node leads to an increase in GIC in the rest of the grid
- Depending on how the node is removed, separating parts of the grid can also lead to a decrease in GIC

- More future work can develop realistic GIC mitigation strategies
Measurements – Example

Evaluation period 23rd Apr 2017

Max = 3.3 A
Max = 1.0 A
Max = 1.2 A
Extreme scenario

• 2003 (Halloween) geomagnetic storm:

Geomagnetic field and modeled GIC during 29-30 Oct 2003

Max = 9.3 A
Plans

• Past work:
  – Halbedl et al. (2014): Measurement and analysis of neutral point currents in a 400-kV-network
  – Halbedl et al. (2016): Analysis of the impact of geomagnetic disturbances on the Austrian transmission grid
  – Bailey et al. (2017): Modelling geomagnetically induced currents in mid-latitude Central Europe using a thin-sheet approach

• Future work:
  – Establish a Space Weather Competence Centre in Austria
  – Build contact with interested parties (APG, ÖBB, etc. …)
  – Monitor and study space weather and regional/national impacts
  – Ensure quick communication in space weather events
Summary

• Magnitude of GICs in Europe are not insignificant

• GIC in Austria may reach dangerous levels during mild storm

• Work is ongoing in Austria to **study, monitor and predict** space weather events
Thank you!
Extra: Station Locations
Model & Measurements

• Thin-sheet model (Vasseur and Weidelt, 1977):
  – Quasi-3D model with lateral conductivity variations at surface
  – Input: $\frac{d\mathbf{B}}{dt}$ and $\rho(x, t)$
  – Output: $\mathbf{E}(x, t)$

• Grid circuit model (Kirchoff and Ohm‘s laws), Lehtinen-Pirjola 1984 method:
  – Input: $\mathbf{E}(x, t)$ and $\mathbf{M}_{\text{network}}$
  – Output: GIC in all stations

• Compare to measurements of DC in transformer:
  – Conducted by the Austrian Power Grid over past two years
GIC in Austria – Model Observations

• Strongest currents found at edges of long lines
• Network is most susceptible to strong $E_x$ fields/E-W geomagnetic variations
• No one station/area is particularly susceptible to extreme currents
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