# Geomagnetically Induced Currents in Austria

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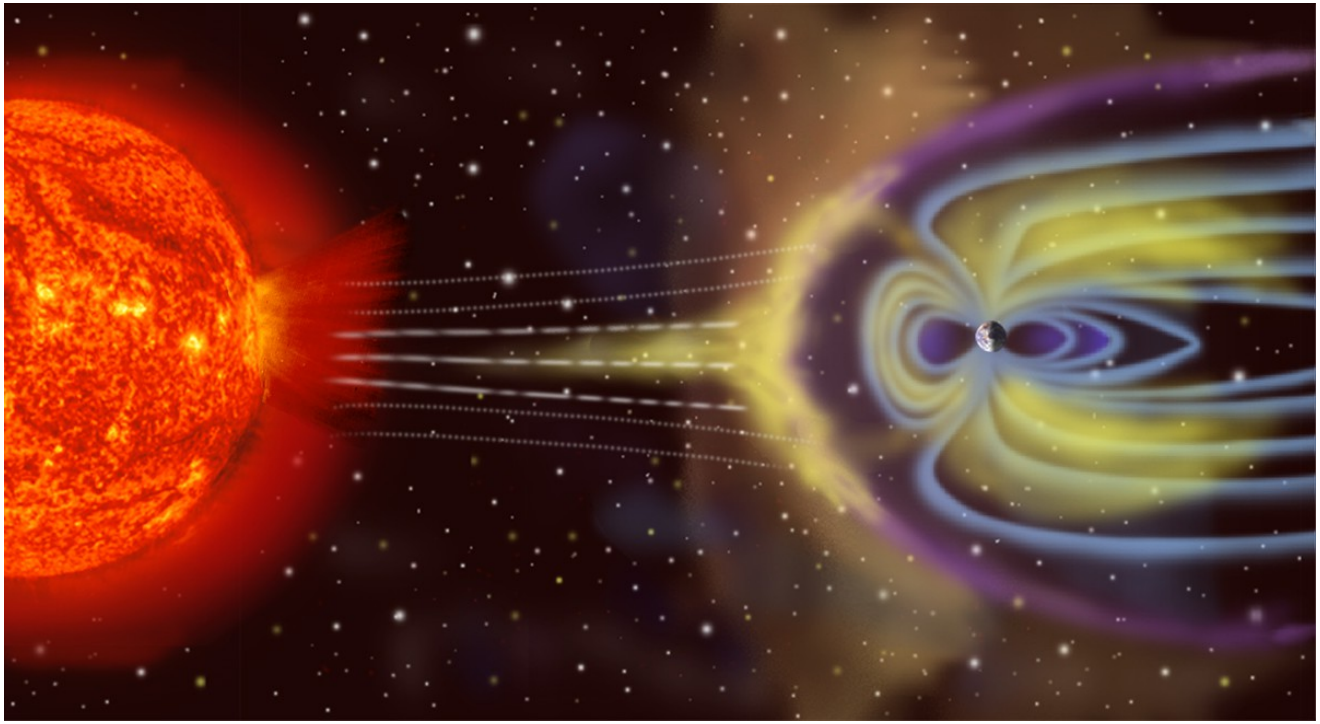
# Geomagnetically Induced Currents (GIC)



Credit: NASA

Enhanced electrojet and rapid variations seen in geomagnetic field

Solar eruption,
Coronal mass ejection (CME)

Cloud of energetic particles hits Earth‘s magnetosphere

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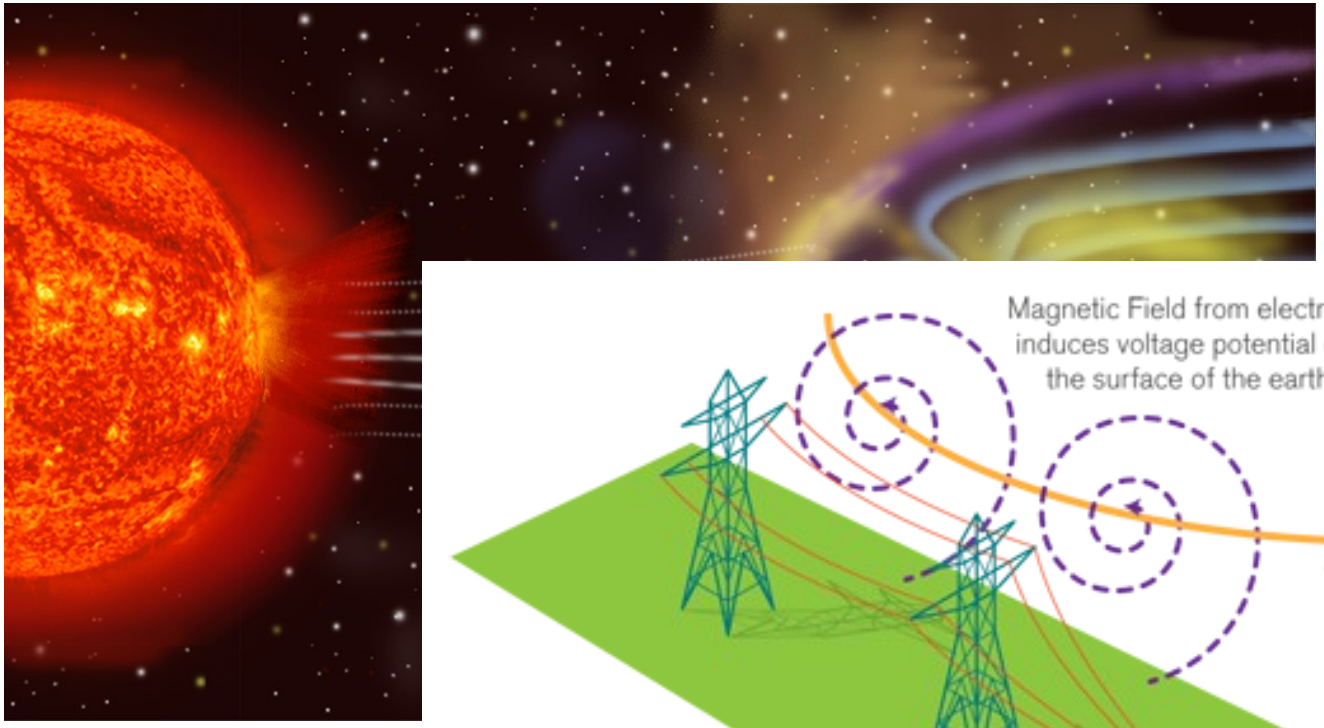

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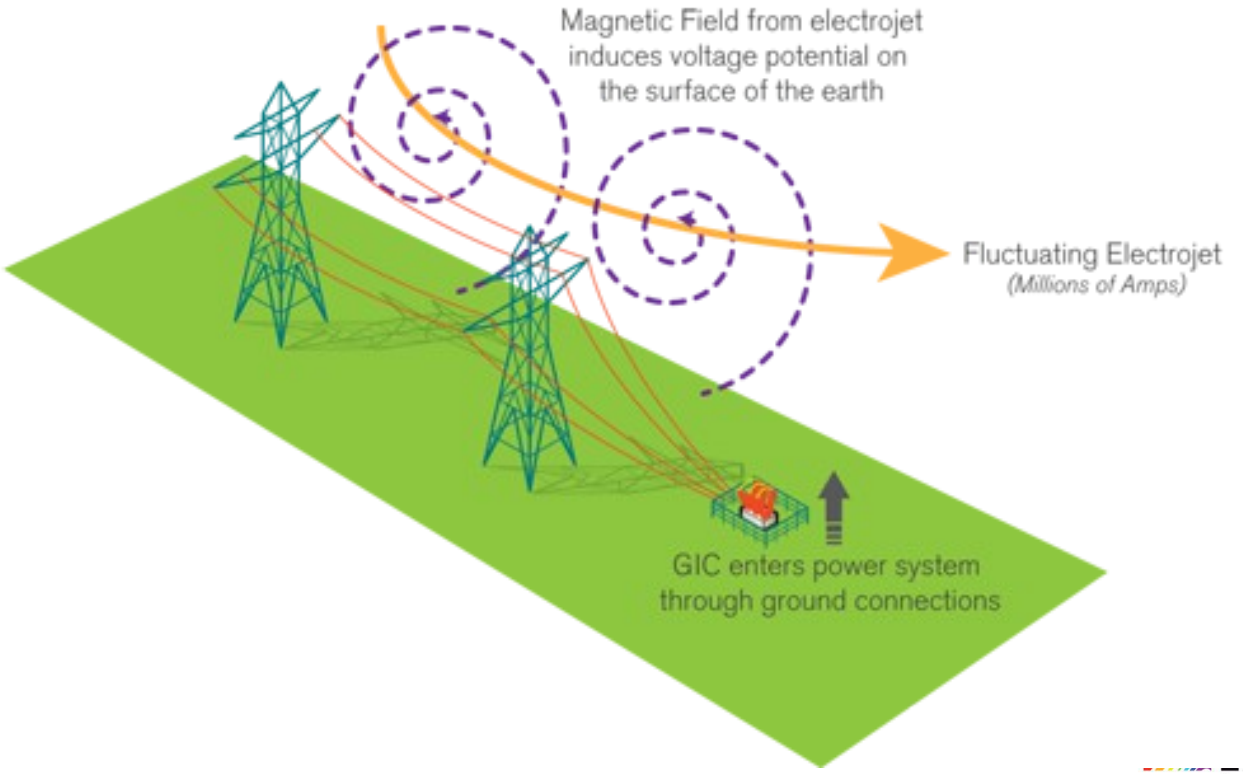
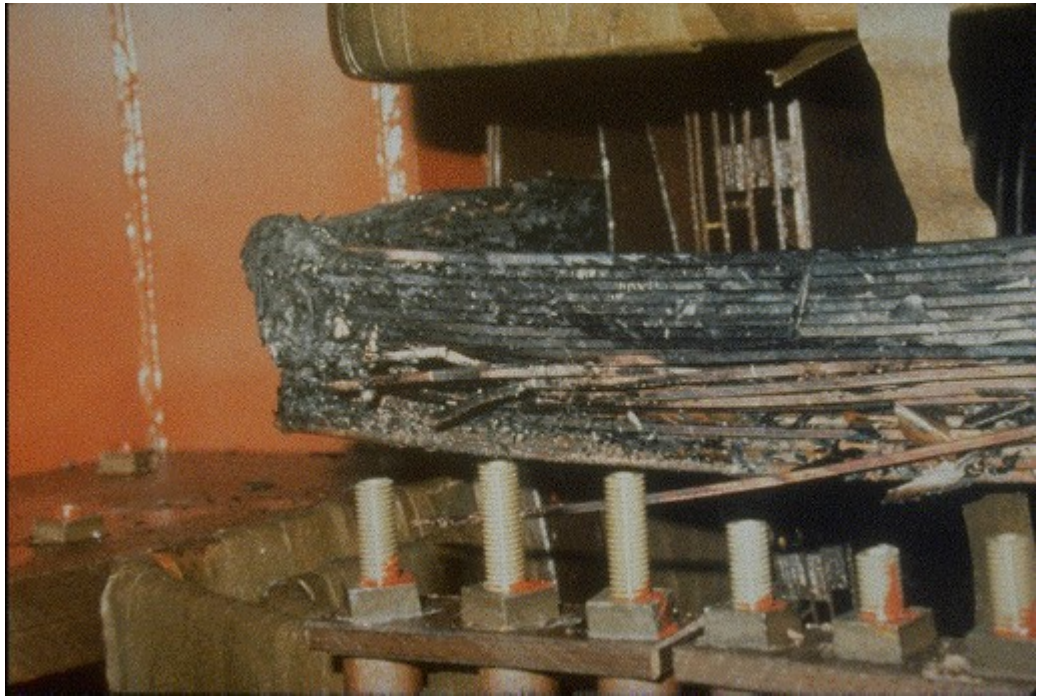



Credit: SPX Transformer Solutions

# GIC?

March 13th 1989

Quebec without power for 9 hours



Credit: PS&E



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# 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

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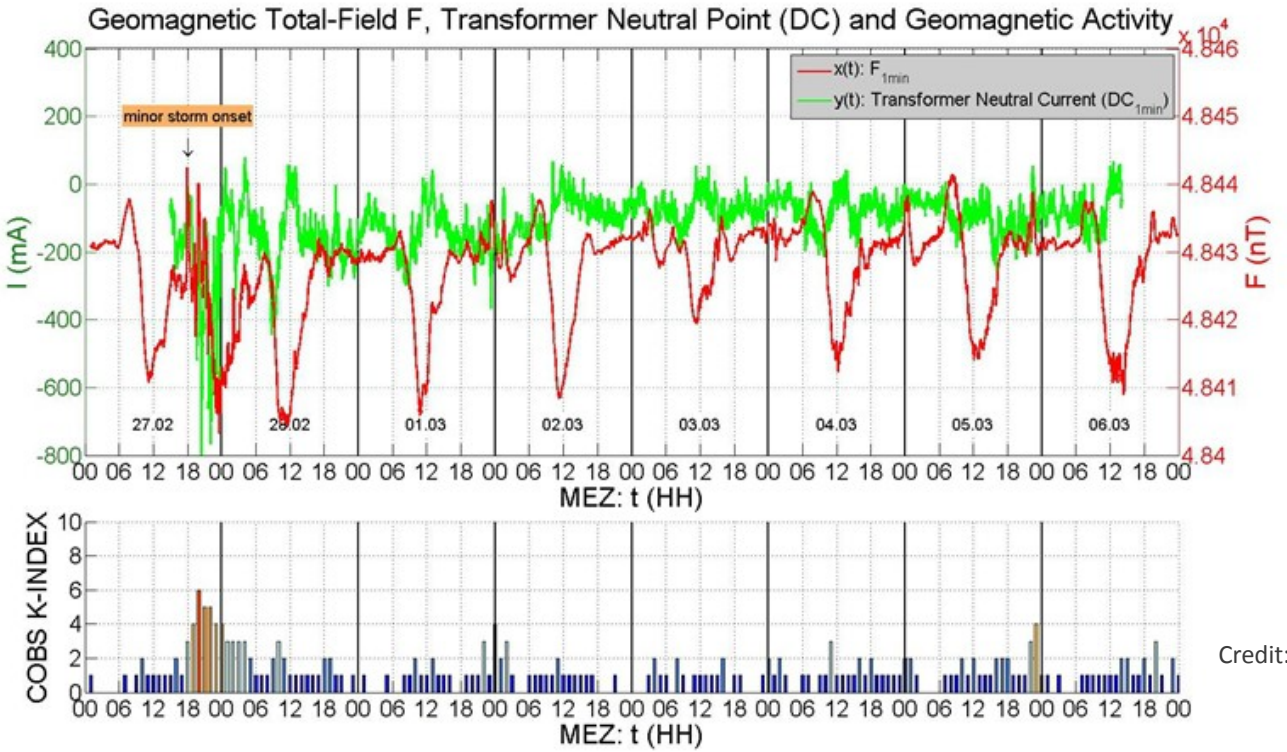


Credit: APG

- Studies are important for **risk analysis** of the impact of GIC



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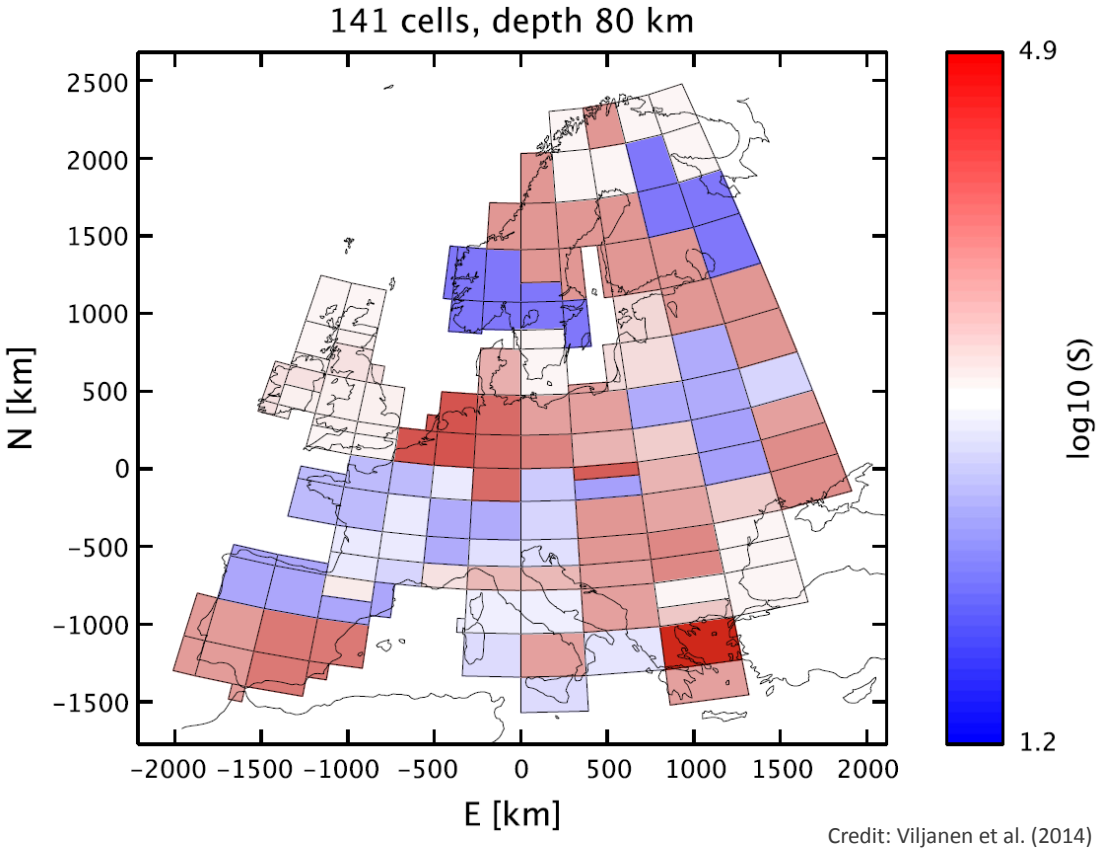
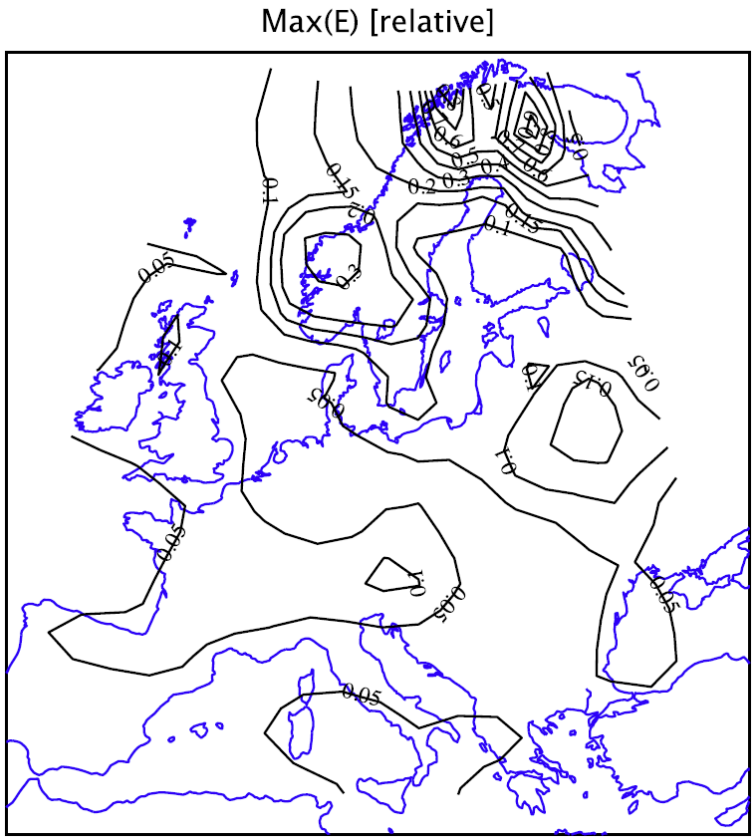
# Why Austria?

- 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

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# Basic Data

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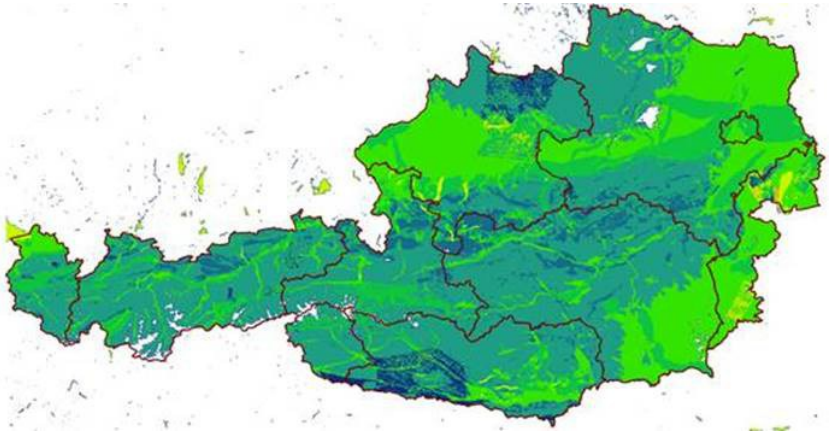

Credit: GBA



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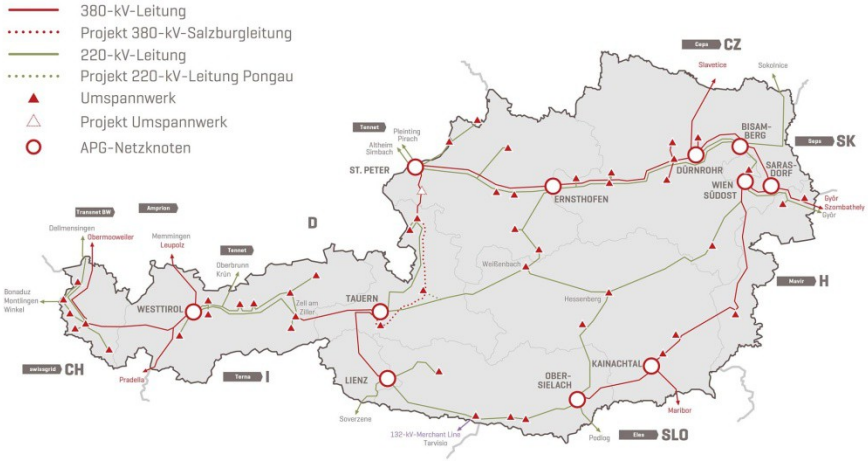
- **$M_{network}$** … power network topology
  - Provided by power grid operators
  - Need all parameters
  - Includes surrounding countries




Credit: APG

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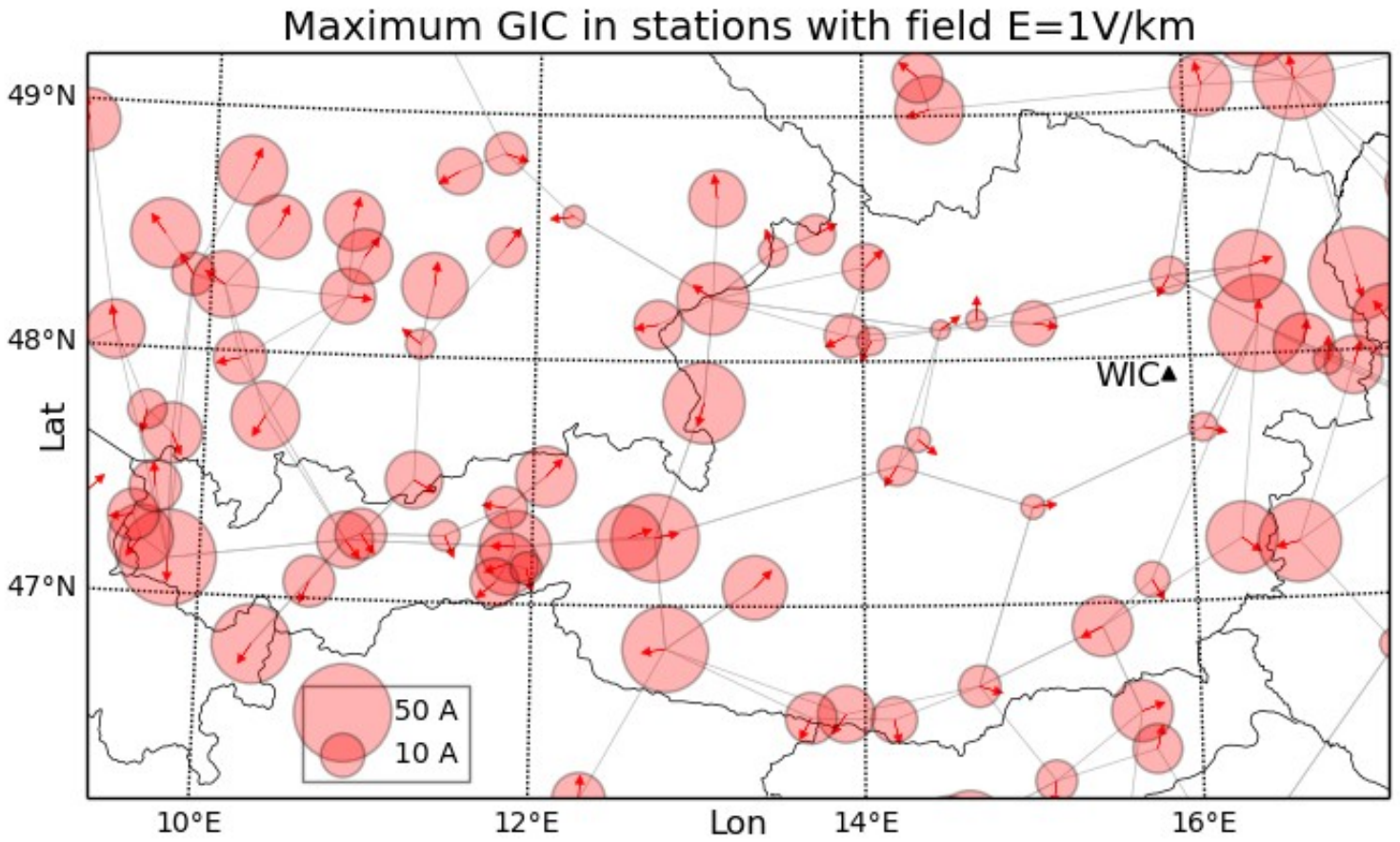
# Scenario: Strong geoelectric field

- Scenario: *1 V/km geoelectric field --> max*. GIC = **49.13 A** near **Vienna**



# Scenario: Removal of station from grid

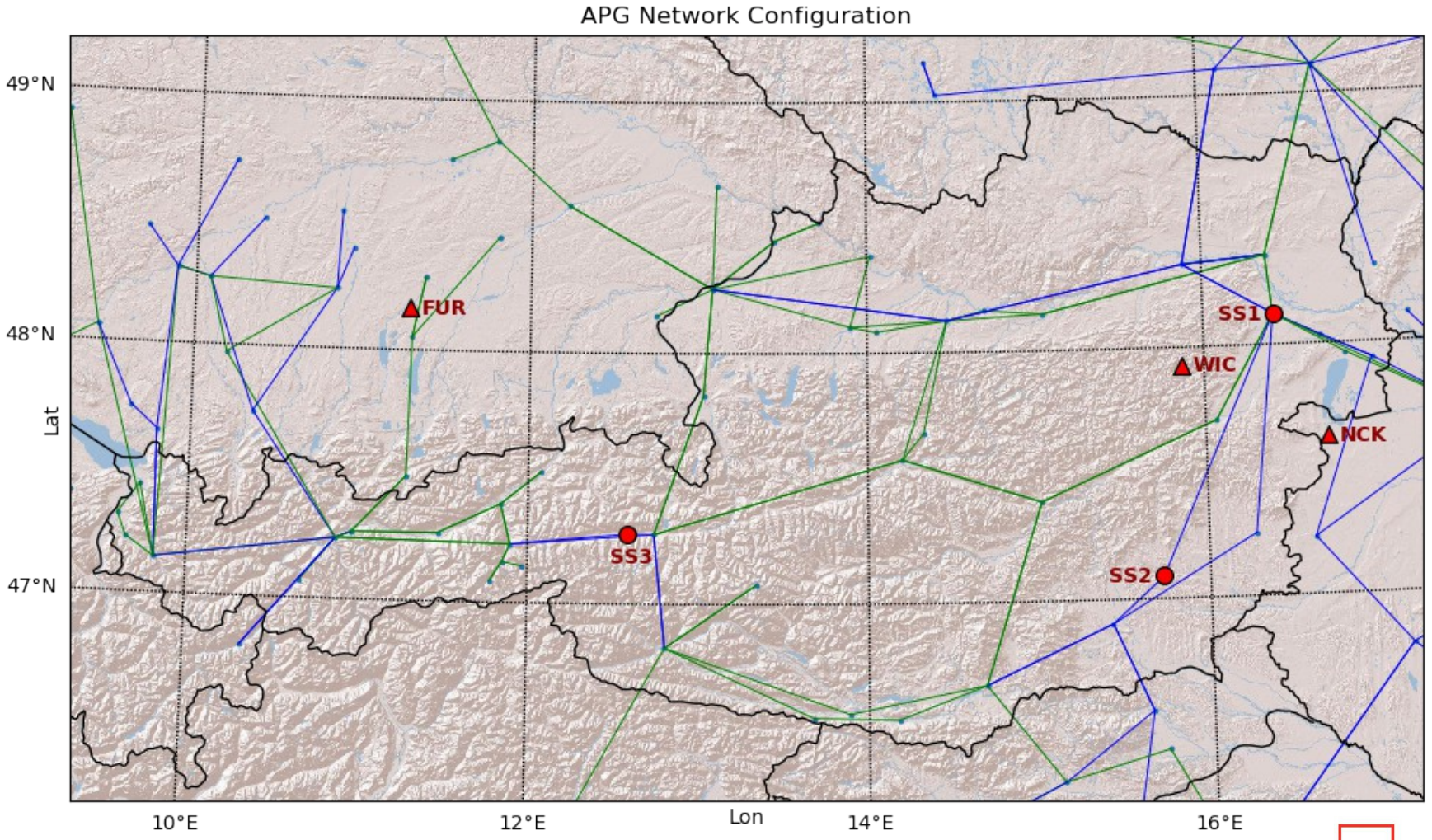
- Stations in 380 kV grid with greater distances to connecting nodes are most susceptible to large GIC
- → The same nodes cause large increases in GIC elsewhere when removed

- 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 – Stations

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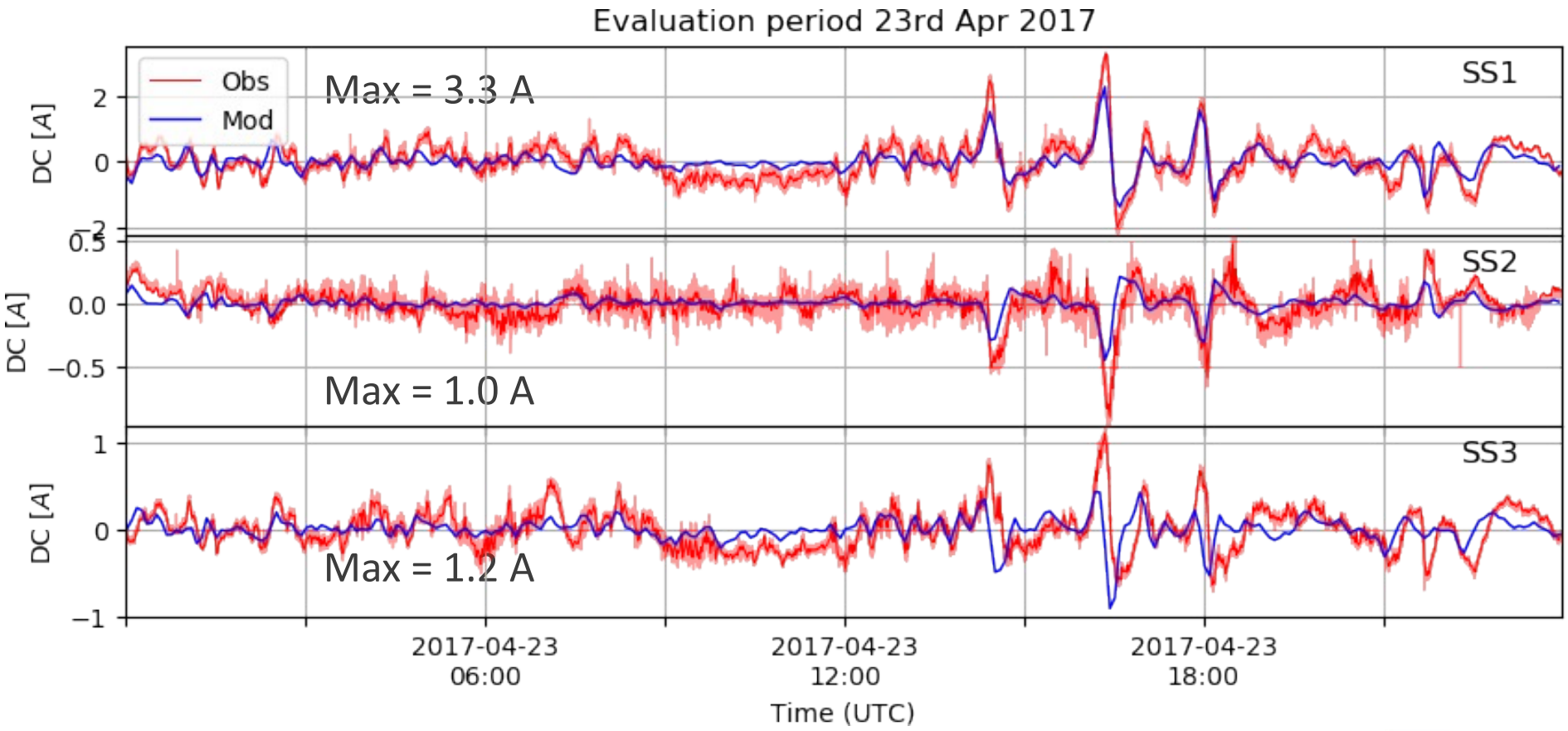
# Measurements – Example

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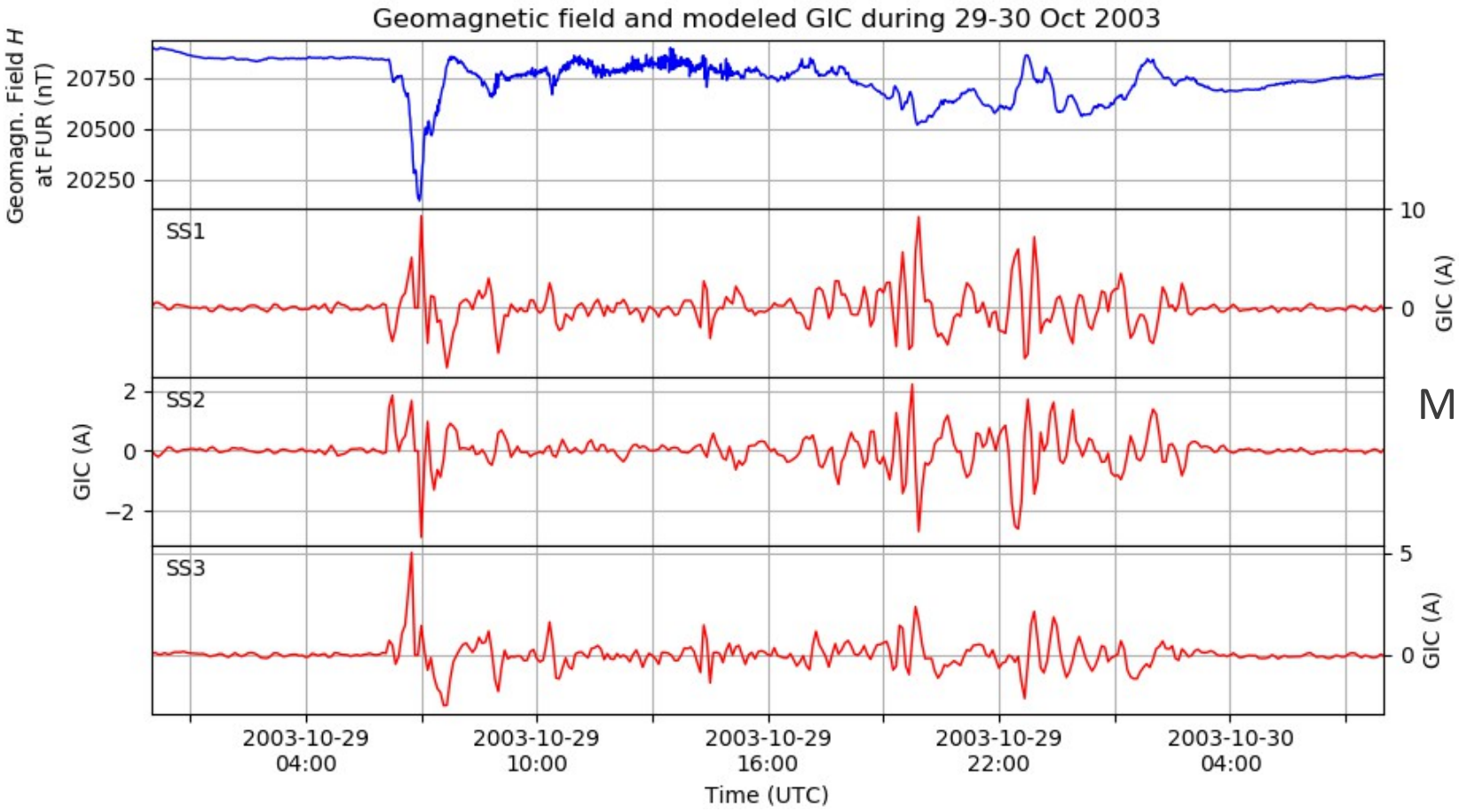
# Extreme scenario

- 2003 (Halloween) geomagnetic storm:




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

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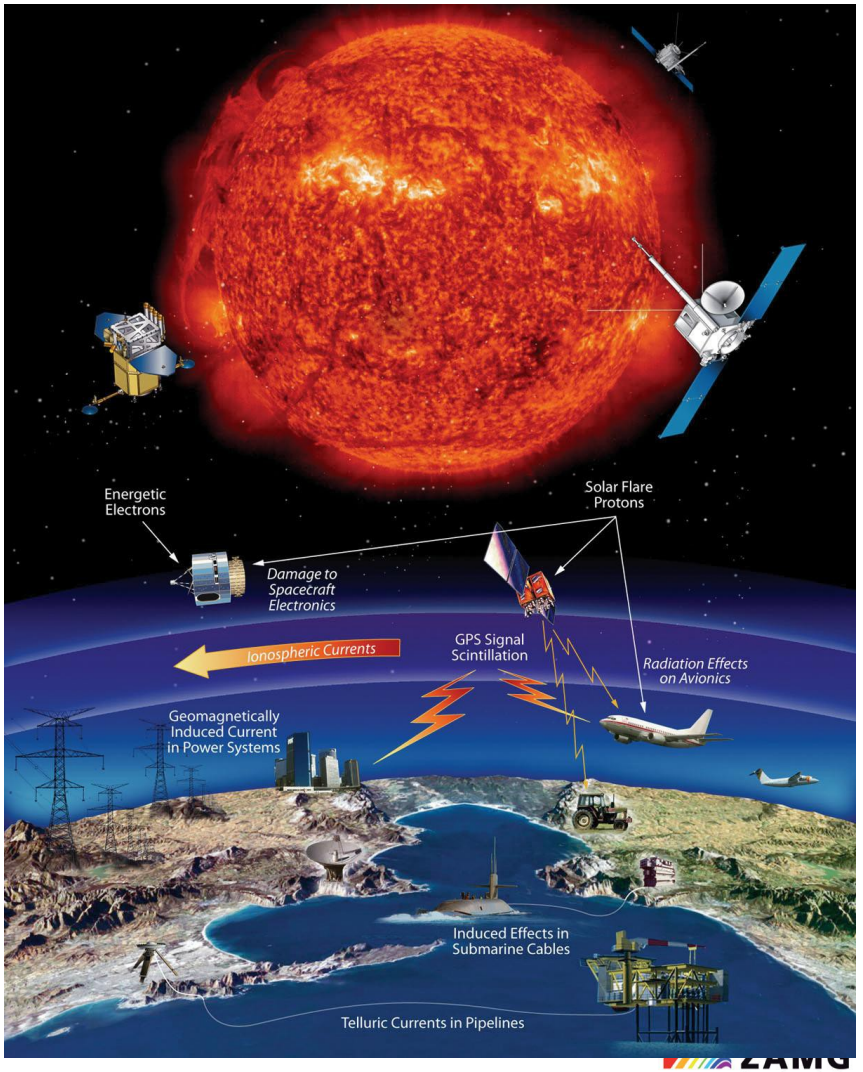
# Summary

- 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**

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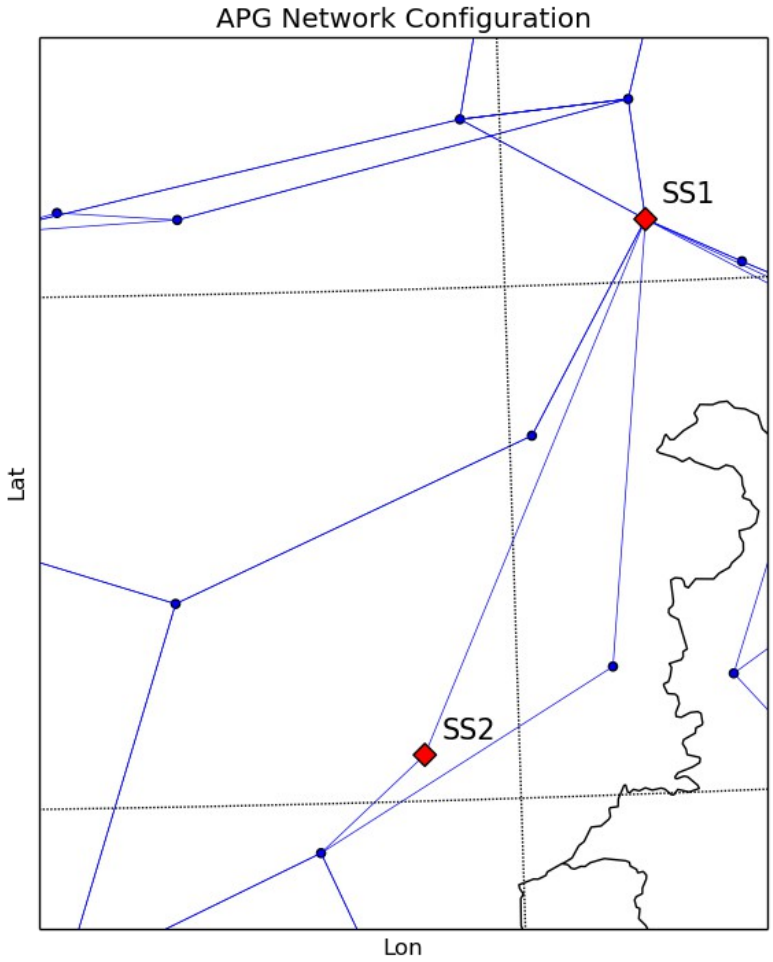
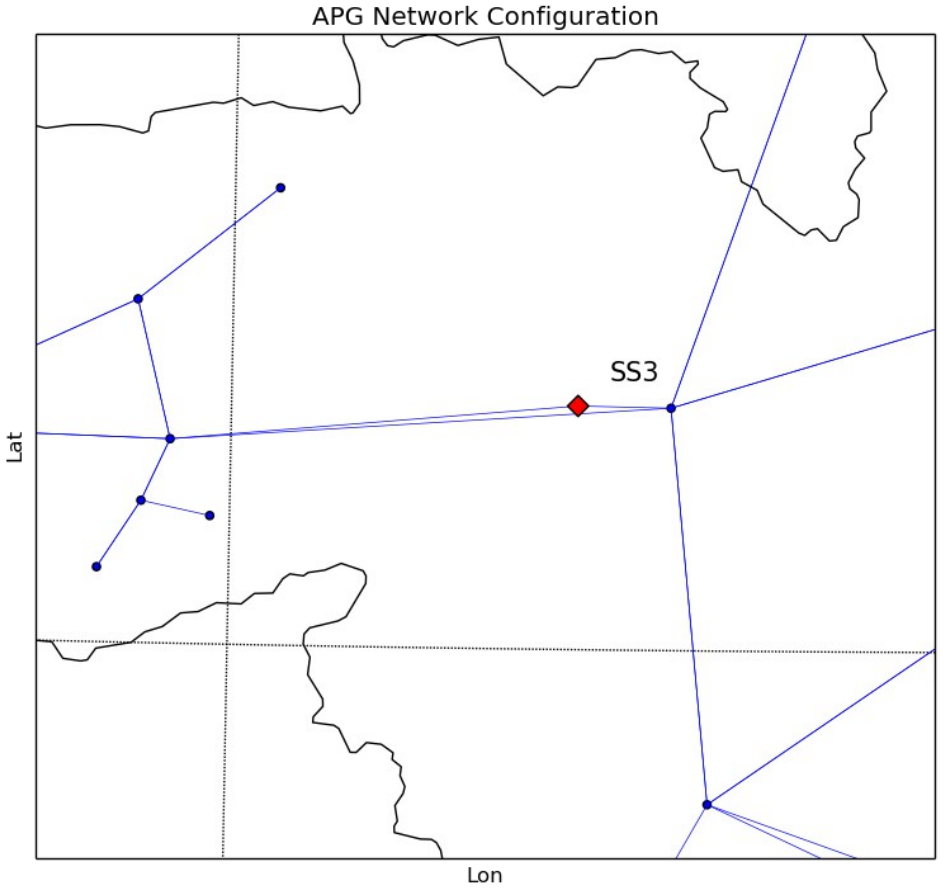
# Fin

# Extra: Station Locations

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# Model & Measurements

- Thin-sheet model (Vasseur and Weidelt, 1977):
  - Quasi-3D model with lateral conductivity variations at surface
  - *Input*: **dB/dt** and **ρ(x, t)**
  - *Output:* **E(x, t)**

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

- Compare to **measurements of DC in transformer**:
  - Conducted by the Austrian Power Grid over past two years

Credit: APG

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# 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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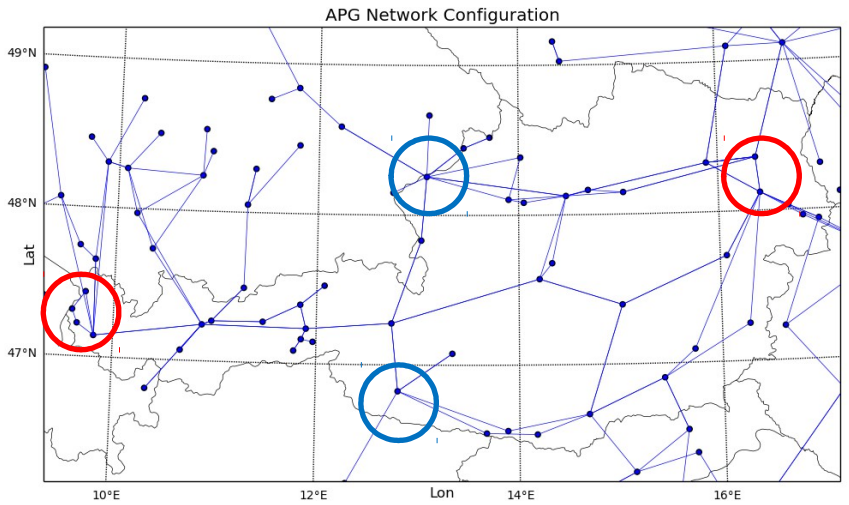




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- Scenario: *1 V/km geoelectric field*

  max. GIC = **49.13 A** near **Vienna**