Geomagnetically Induced Currents and Space Weather Prediction in Austria

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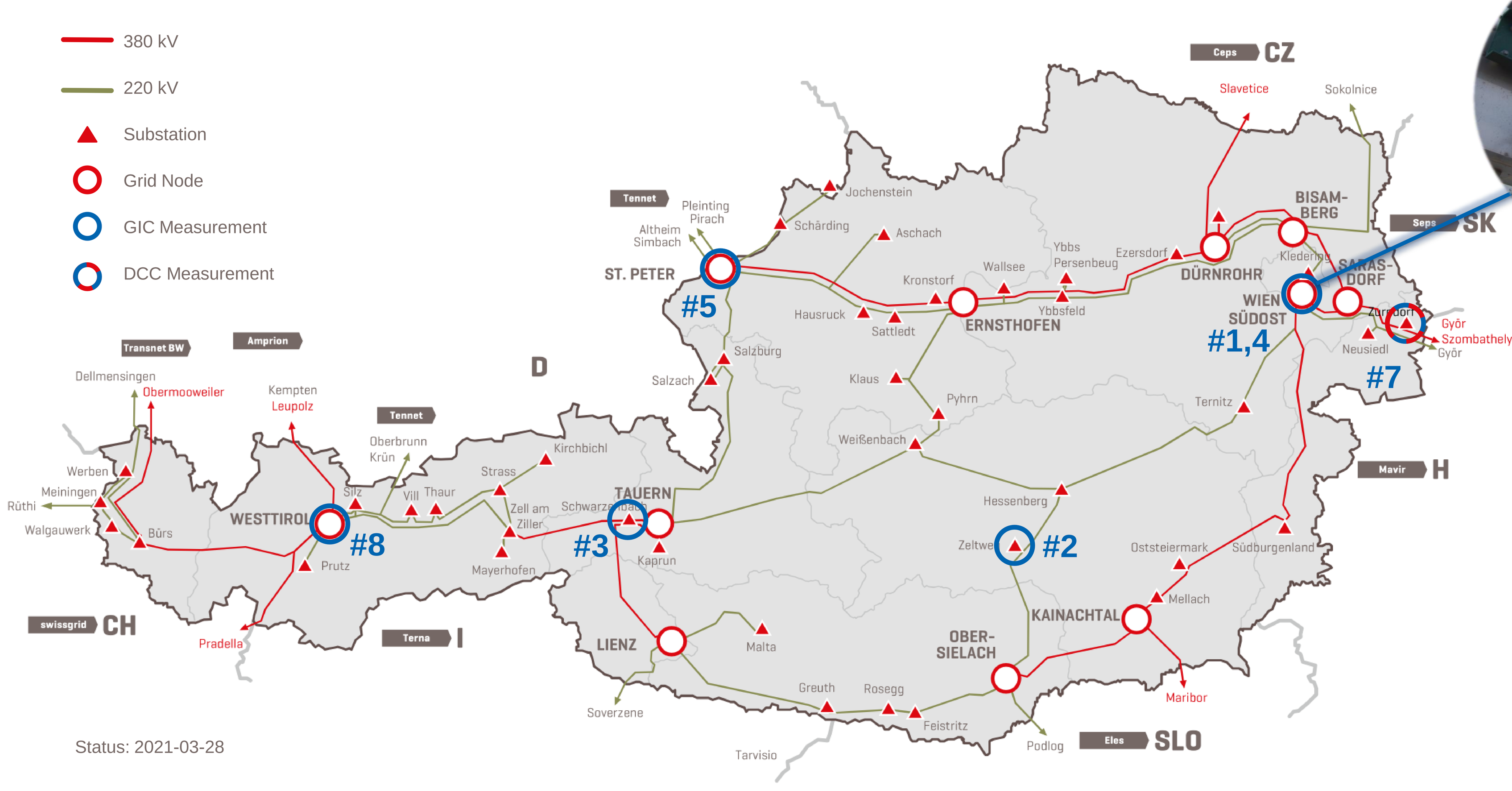
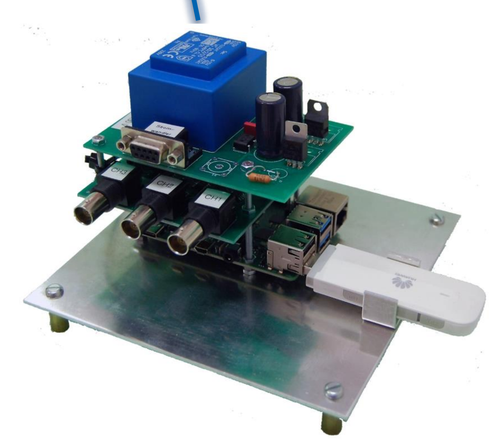
Austria - Some Statistics

Population: 8.9 million
Size: 84 000 km² (600 km wide)
Neighbouring countries: Switzerland, Germany, Czechia, Slovakia, Hungary, Slovenia, Italy, Lichtenstein (8)
Geomagnetic latitude: 46°

Power Grid Operator: Austrian Power Grid (APG)
No. of HV substations: 54
No. of GIC measurement devices: 7

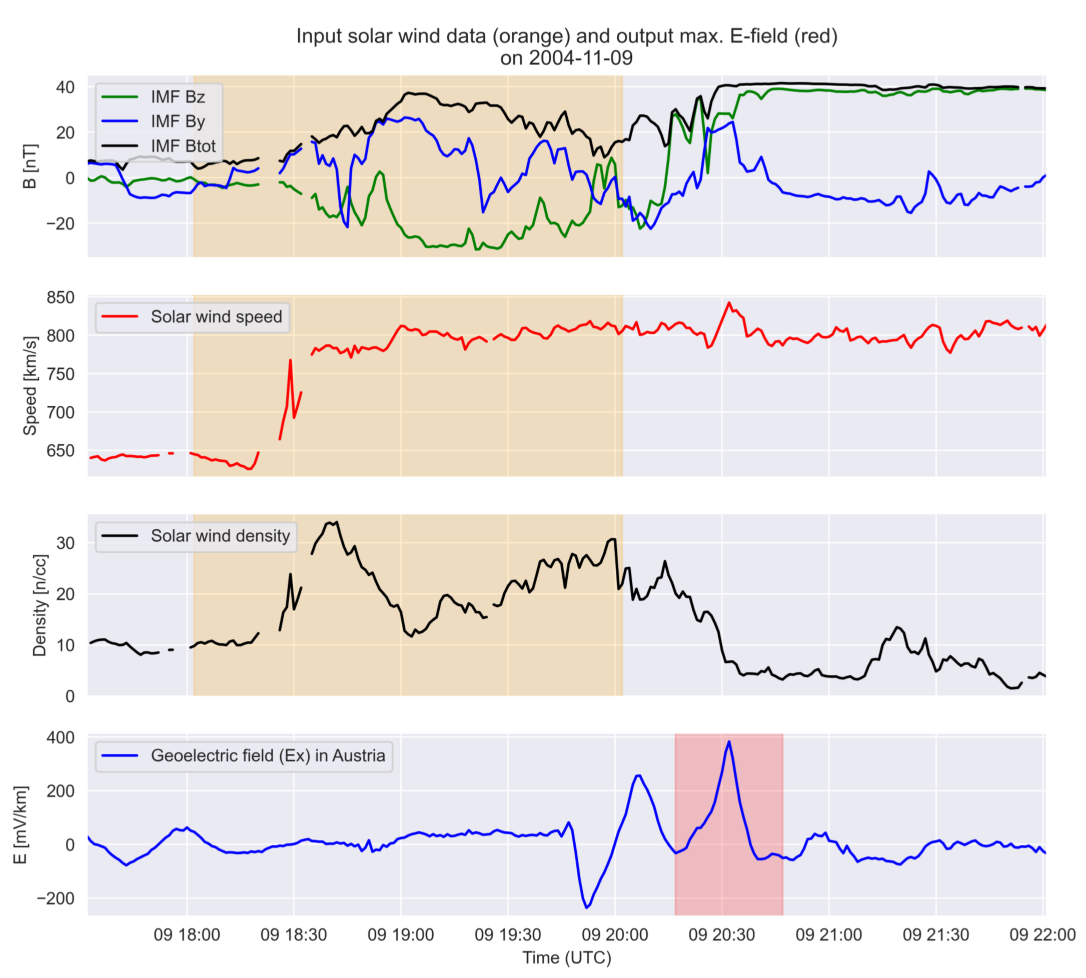




Space Weather Prediction

Current Work

- Developing a forecasting model using machine learning (recurrent neural networks)
- **Data**:
  - 26 years of data from 1995 til 2021
  - OMNI solar wind (back-propagated to the Lagrange-1 point)
  - Regional geoelectric field modelled from local geomagnetic variations using the plane wave approach and a subsurface resistivity layer model (validated against measured GICs in transformers after putting the geoelectric field through a model of the power network).
- **Input**: Solar wind data from the Lagrange-1 point with 2-hour history (orange in plot)
- **Output**: maximum expected geoelectric field in the next 30-min following a minimum of ~20-min solar wind expansion time to Earth (red in plot). The field is for the region of Austria, assumed to be homogenous due to the small size of the country.
- **Forecasting model**:
  - LSTM (Long Short-Term Memory recurrent neural network)
  - One model for E_x, one for E_y → combine to forecast **GICs** at individual stations!



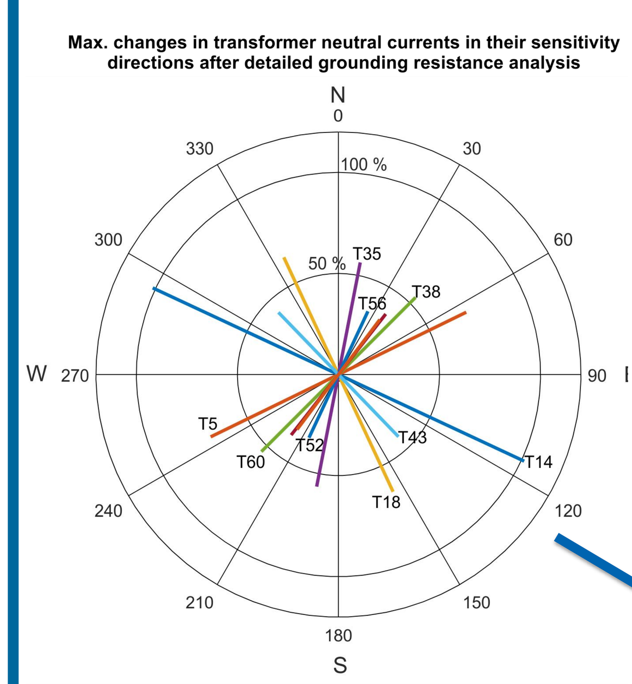
GIC Power Grid Simulation

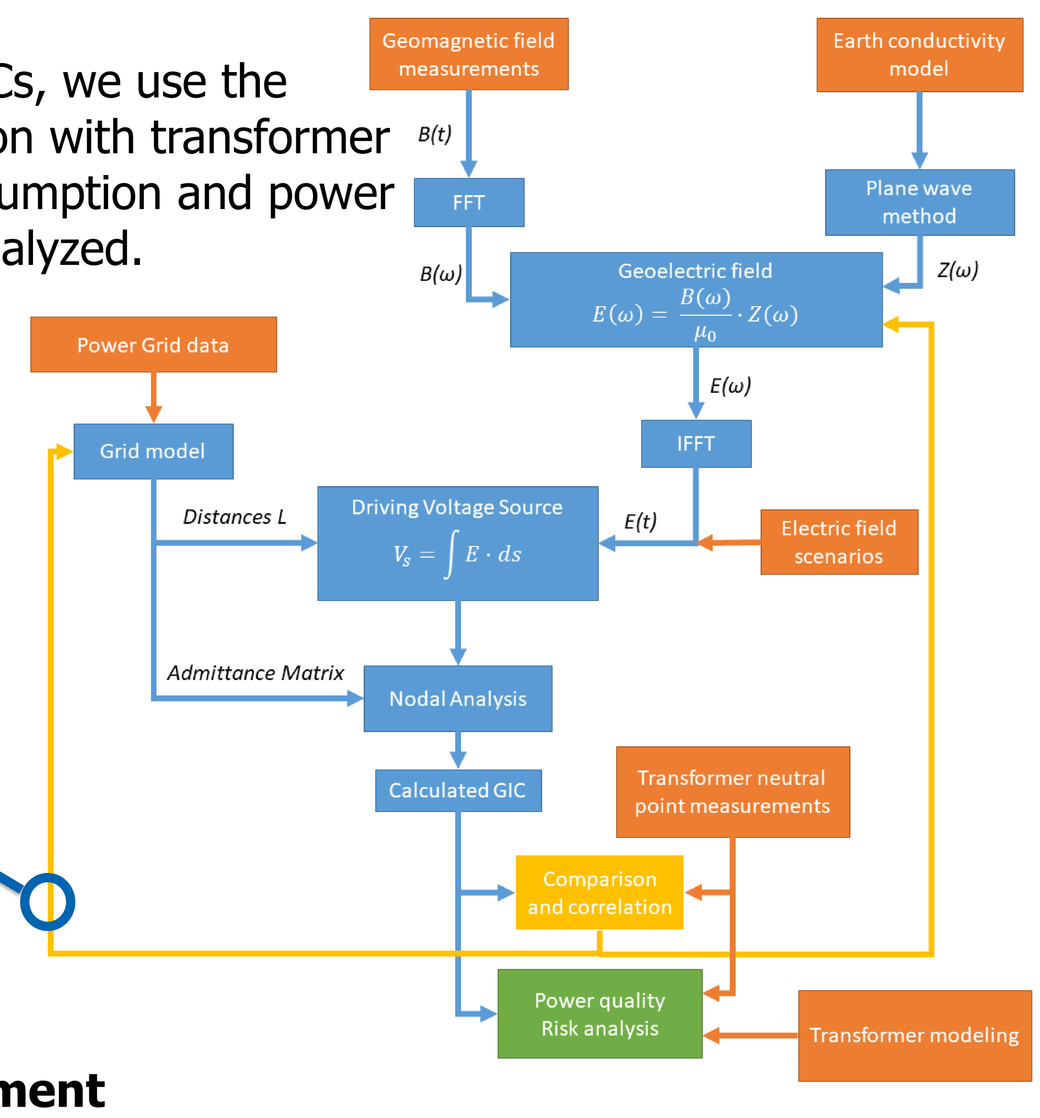
Electric field calculation

The electric field for the GIC calculation is either preset or calculated with the *plane wave* method and *1-D earth conductivity models*.

Power grid calculation

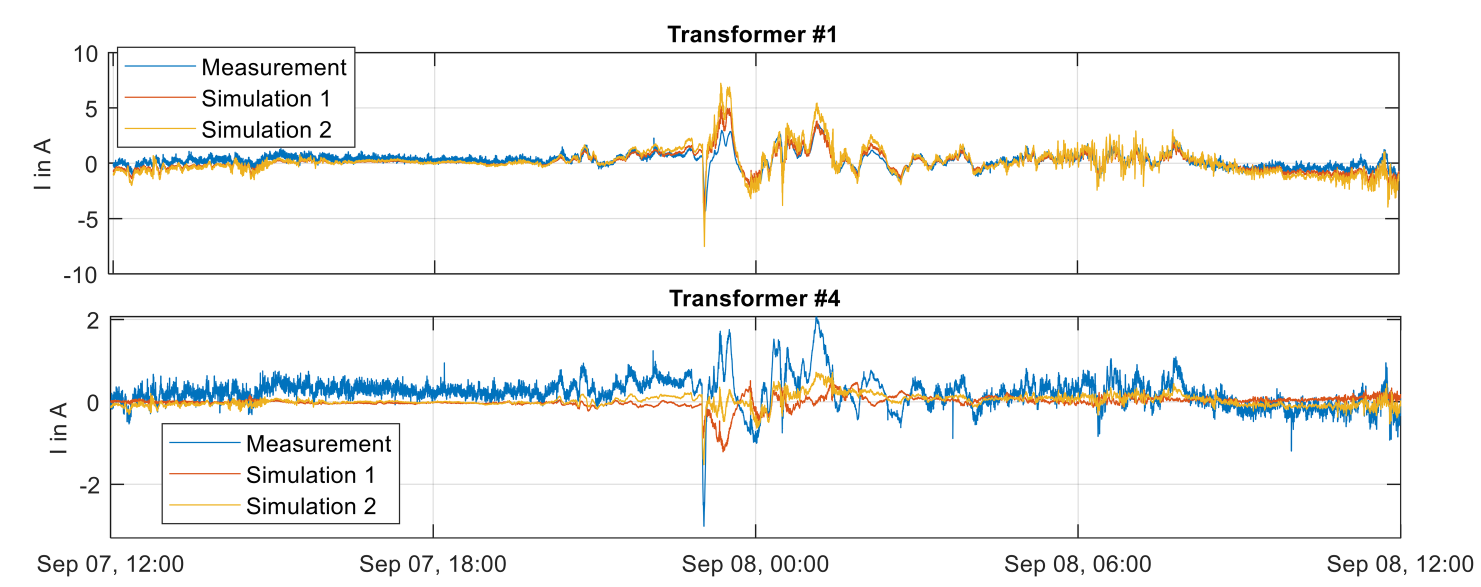
For the calculation of the GICs, we use the *nodal analysis*. In combination with transformer models, reactive power consumption and power quality are calculated and analyzed.





Simulation vs. measurement

We compare our simulation results with our measurements. Thereby, we identify the influence of standard values or unknown parameters and improve our calculations and models.



GIC Measurements & Effects on Power Transformers

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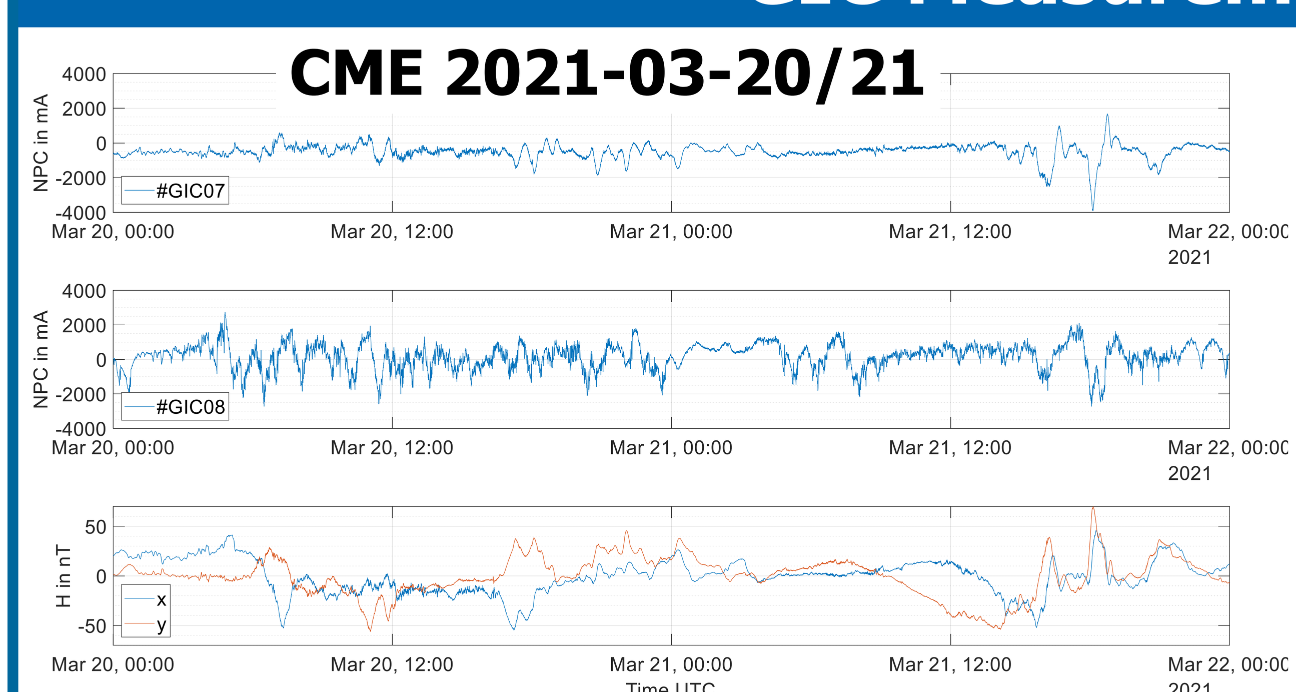
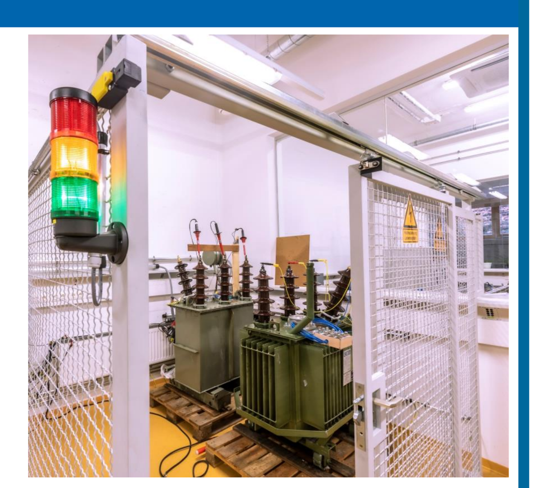


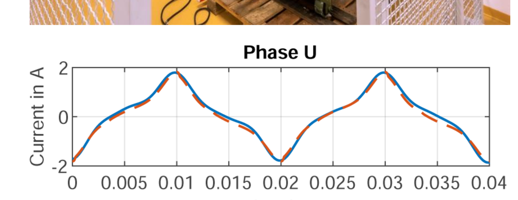
- Max. GIC: 4,000 mA @ 380 kV neutral
- Max. $\Delta H_x/dt$: 38 nT/min.

Low Frequency Currents (LFC), such as GICs, can also be caused by man-made systems, such as DC transportation systems or power electronic systems. These LFC can cause transformer half-cycle saturation, which causes an increased reactive power demand of the transformer. As a consequence, voltage instabilities and, in the worst case, blackouts can occur.

Ongoing Research

- Topology based transformer models
- (On-site) hysteresis measurements
- Reactive power demand measurements and simulation
- Transformer sound level measurement
- Investigation of DC flux mitigation technique
- Flexible transformer neutral point current measurement





Transformer sound due to GIC
Transformer modification time lapse

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