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Geomagnetically induced currents in Finnish transmission grid

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Agenda

- Finnish power grid characteristics
- Impact of the technical choices in Finnish grid for GIC
- Collaboration between Fingrid and Finnish Meteorological Institute
- Recent solar storm events
- Risk analysis

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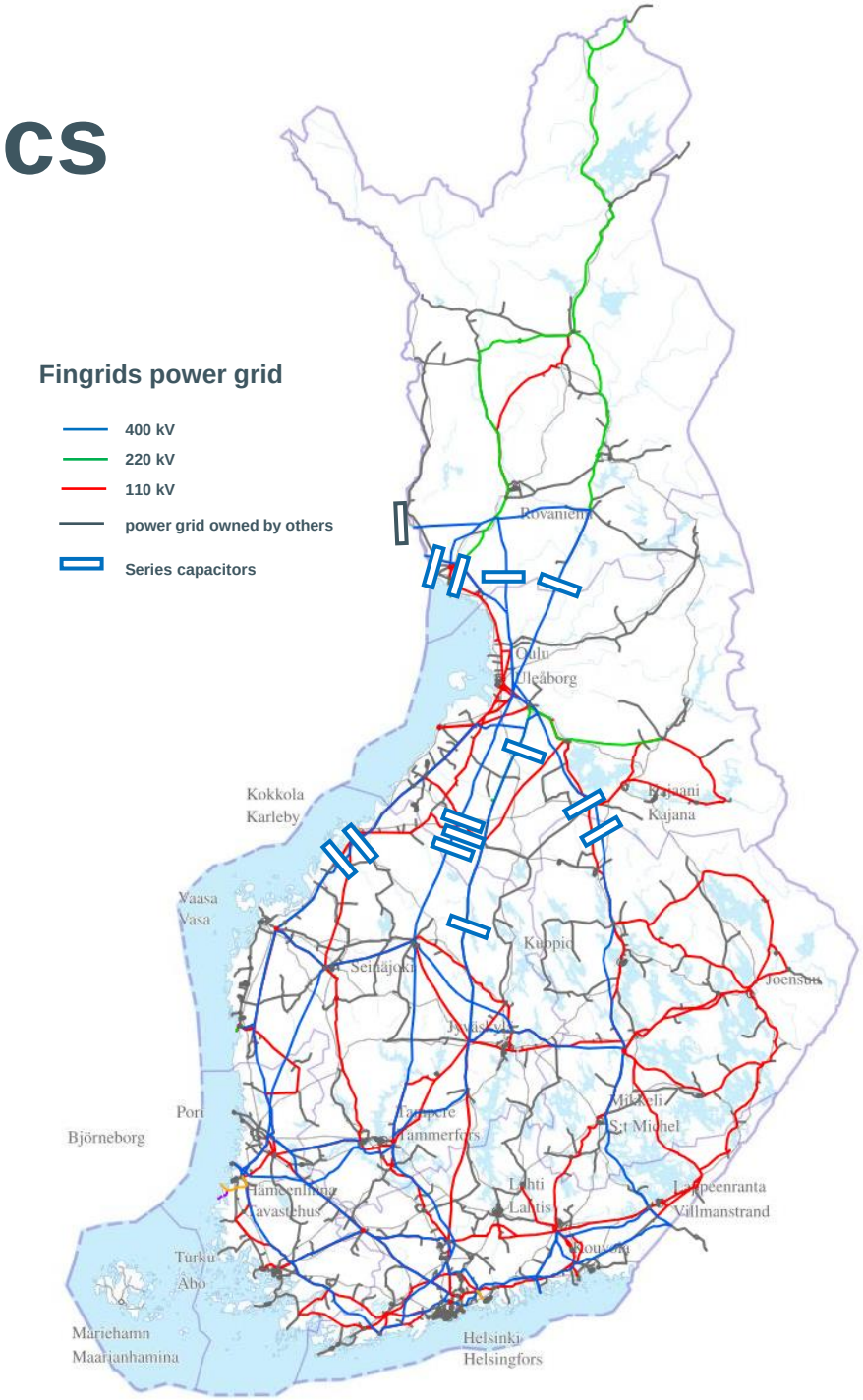
Finnish power grid characteristics

Length of Fingrid’s transmission lines is over 14 500 km.

Number of grounded transformers in Finland:

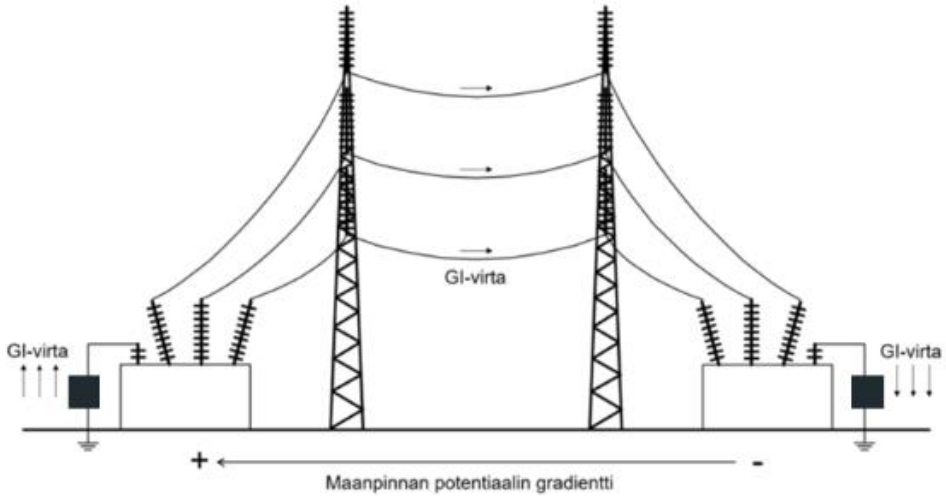
- ~ 90 in 400 kV grid in about 50 substations
- ~ 20 in 220 kV grid in about 20 substations
- ~ 60 in 110 kV grid in about 50 substations

Number of series capacitors 13.



Impact of Technical choices in Finnish grid for GIC

- Full transformers
  - GIC has no path between voltage levels.
- Series capacitors
  - GIC can not flow in 400 kV power lines between Northern and Southern Finland or between Finland and Sweden.
- Earthing reactors
  - No direct earthing in 400 kV grid. Neutrals of 400 kV power transformers are earthed with earthing reactors.
  - Only few transformers may be directly earthed and only in the situations when the earthing reactor in the area is out of service.



S. Lindahl, Effect of Geomagnetically Induced Currents on Protection Systems, 2004. Modified picture.

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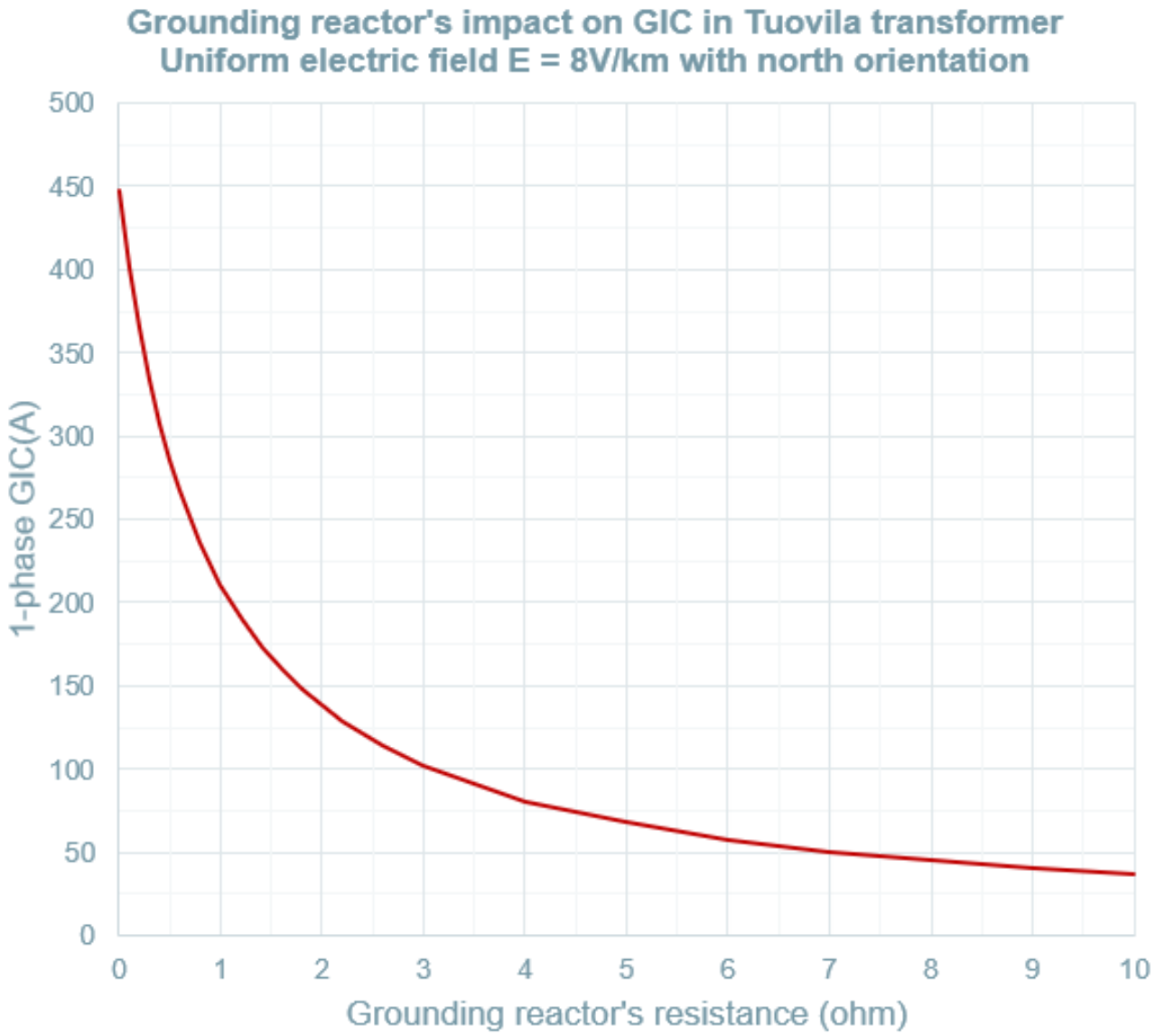
Impact of Technical choices in Finnish grid for GIC



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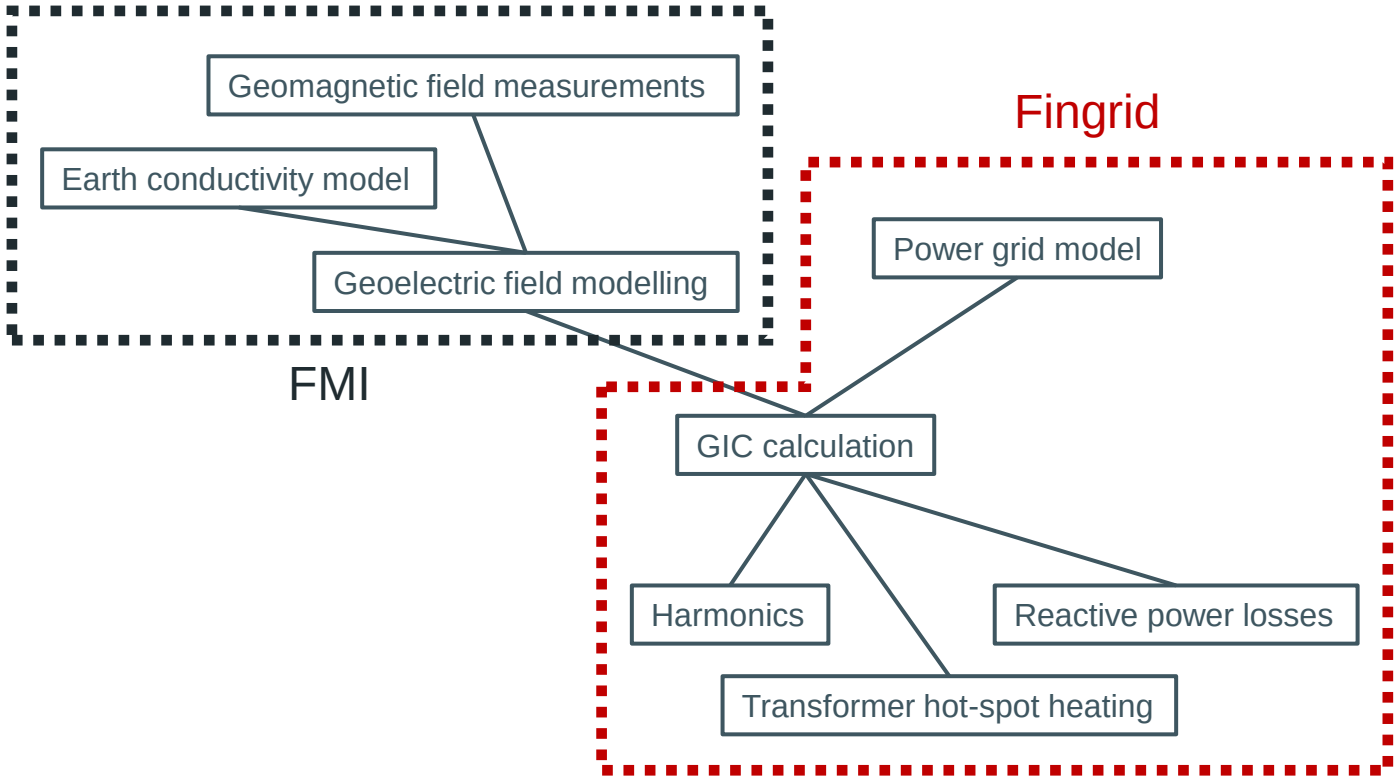
Fingrid and Finnish Meteorological Institute collaboration

- Fingrid and Finnish Meteorological Institute (FMI) have been collaborating since 1970s.
  - GIC simulation steps can be divided to parts which are shown in a figure below:



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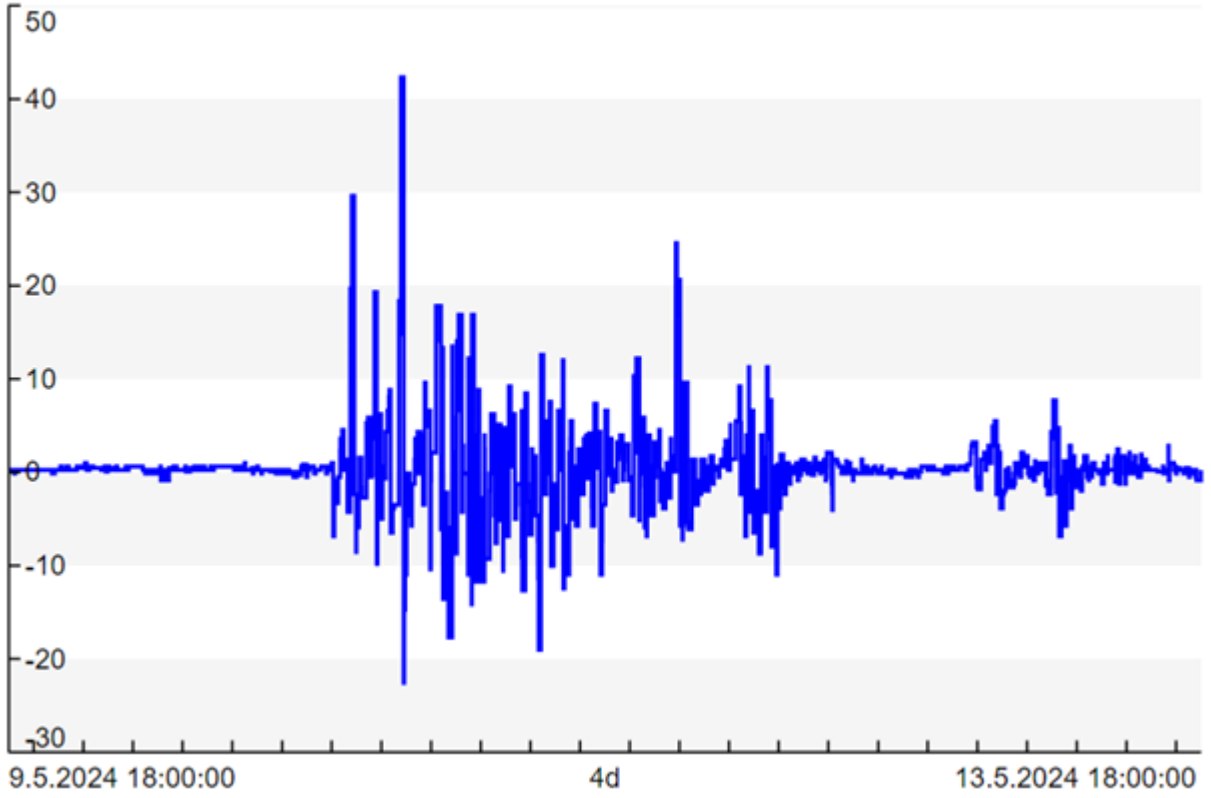
Recent solar storm events

- The most significant event since Halloween 2003 storm occured in May 2024.
  - A current exceeding 40 A was measured in the grid.
  - The current caused ~4 Mvar reactive power consumption in the substation.
  - In the US, a geoelectric field exceeding 9 V/km was measured.
- Last Sunday over 10 A current was measured.
- During past 4 months there have been over 10 smaller events than May 2024 event. The largest of these occured on the 10th -11th of October.



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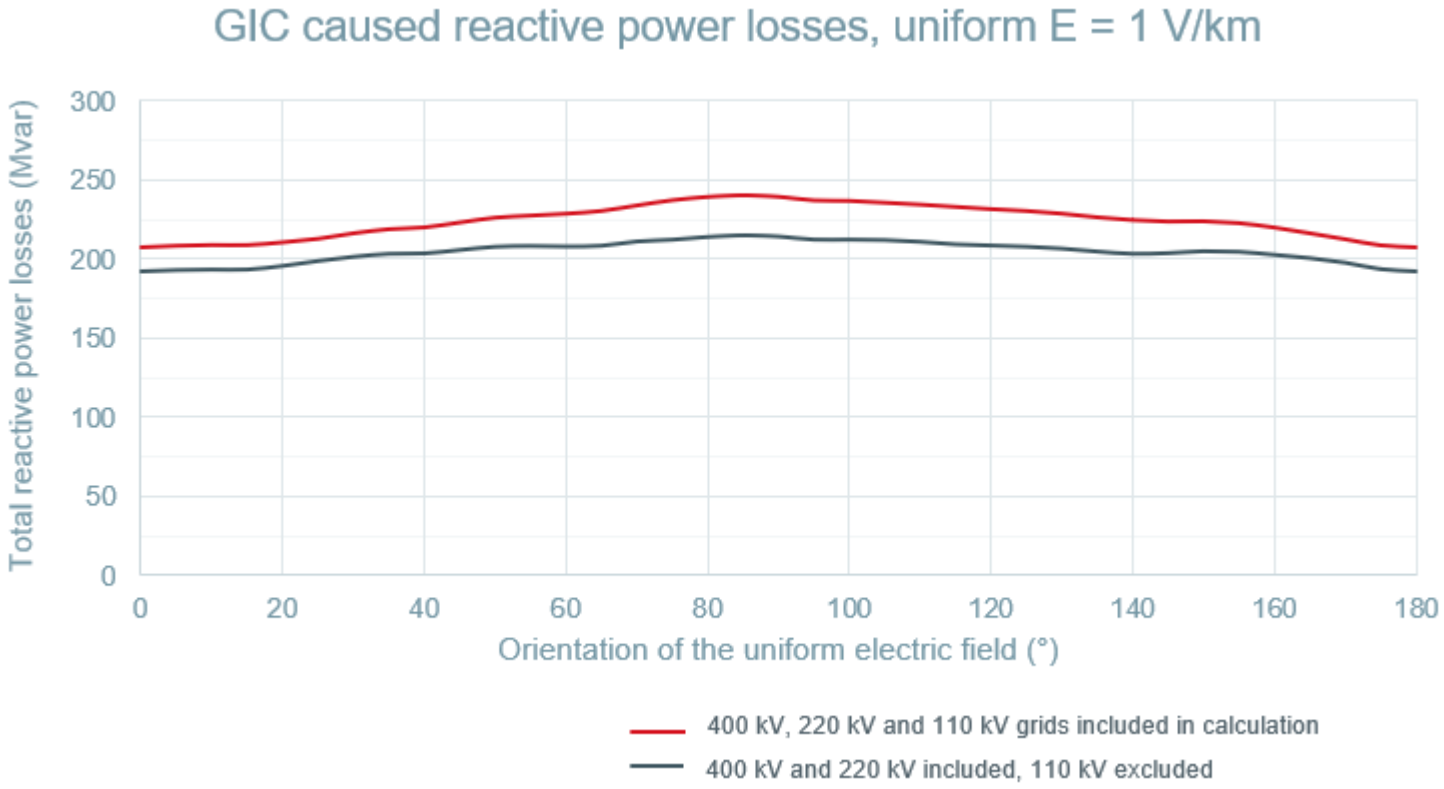
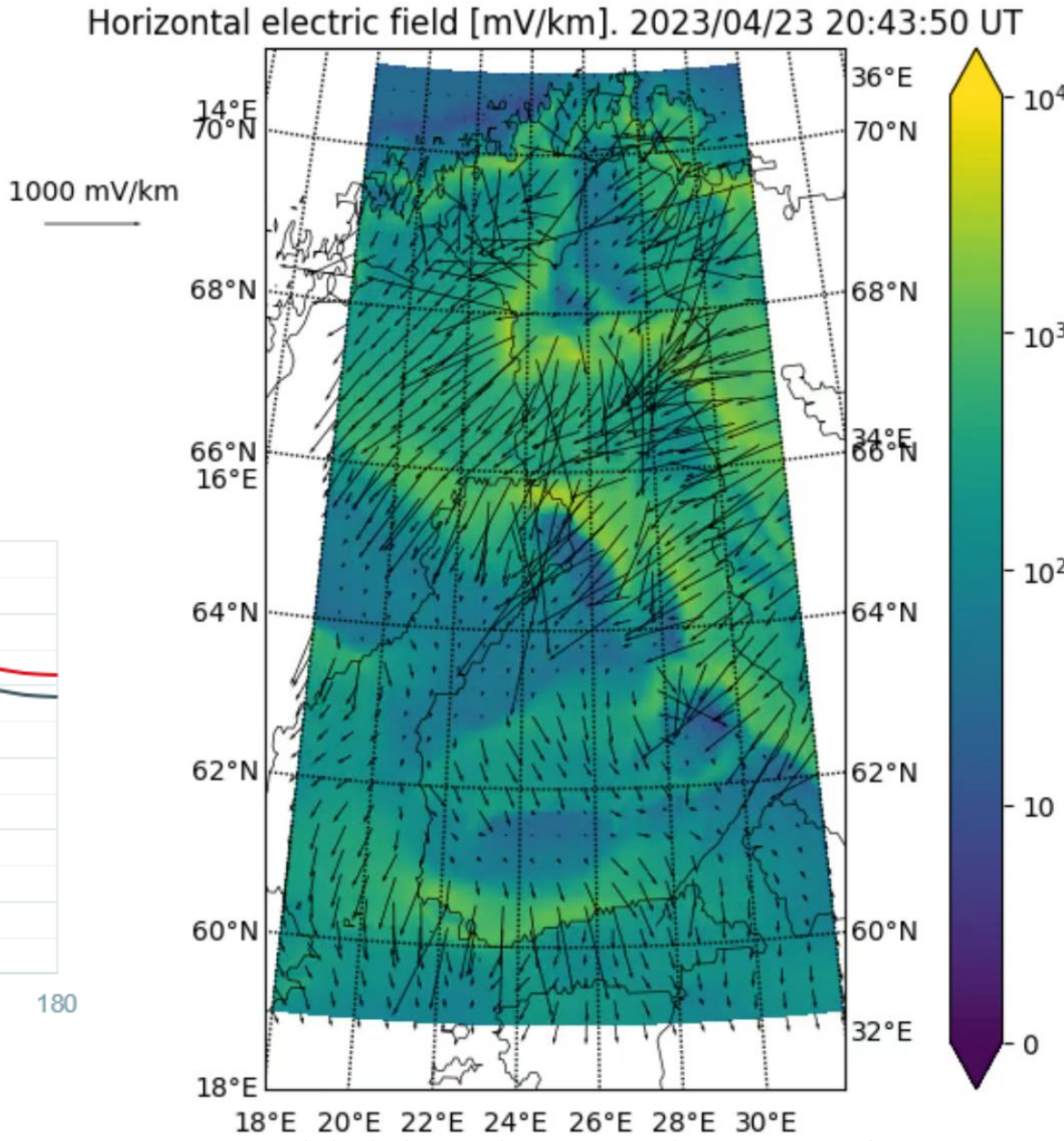
Reactive power losses

- Reactive power losses and uniform electric field magnitude correlate in a linear fashion, f.e. with E=10 V/km reactive power losses are 10x higher than with E=1V/km.





Electric field in Finland during the geomagnetic storm of 23-24 April 2023 modelled using the Multi-Site Transfer Function Approach. E Marshalko, Finnish Meteorological Institute

Risk analysis

Risk analysis is mostly based on benchmark event made by North American Electric Reliability Corporation (NERC).

Voltage stability:

- Simulations show that even in high transfer situations uniform electric field value needs to be around 10–15 V/km to cause problems to the voltage stability.

Transformer hot spot temperatures.

- From GIC test that was done to Fingrid's transformer in 2002 we can approximate acceptable level of transformer hot-spot temperature to exceed when GIC surpass 100 A per phase for several minutes.
- Simulated benchmark event has shown that GIC exceed 100 A current for about 30 seconds.

- Level of Harmonics from transformers during benchmark event has been low compared to other sources of harmonics.

➢ The Finnish grid is quite resilient to GIC, but there is always the question of how extreme the next once-in-a-century event will be.

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Thank you!

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