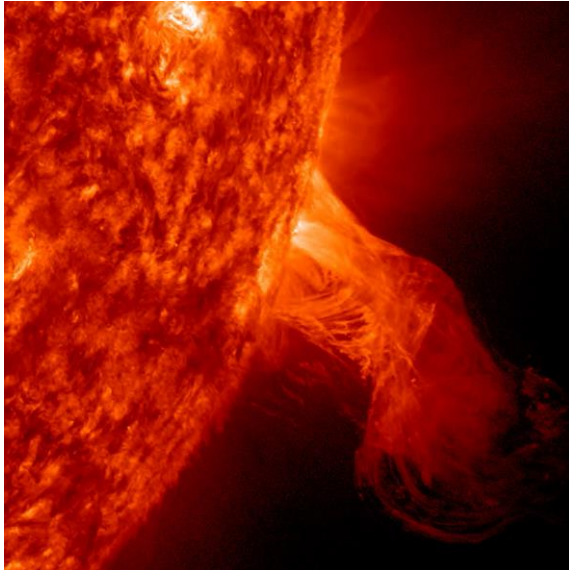


Effects of Solar Storms on the Power Grid

Philipp Schachinger, Dennis Albert

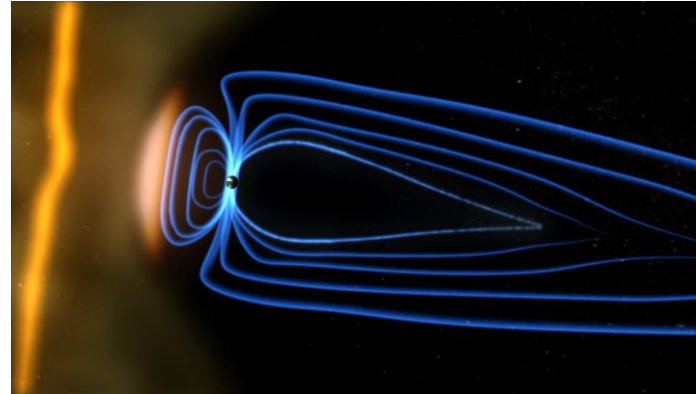
April 7th, 2022

GIC's & Geomagnetic Induction



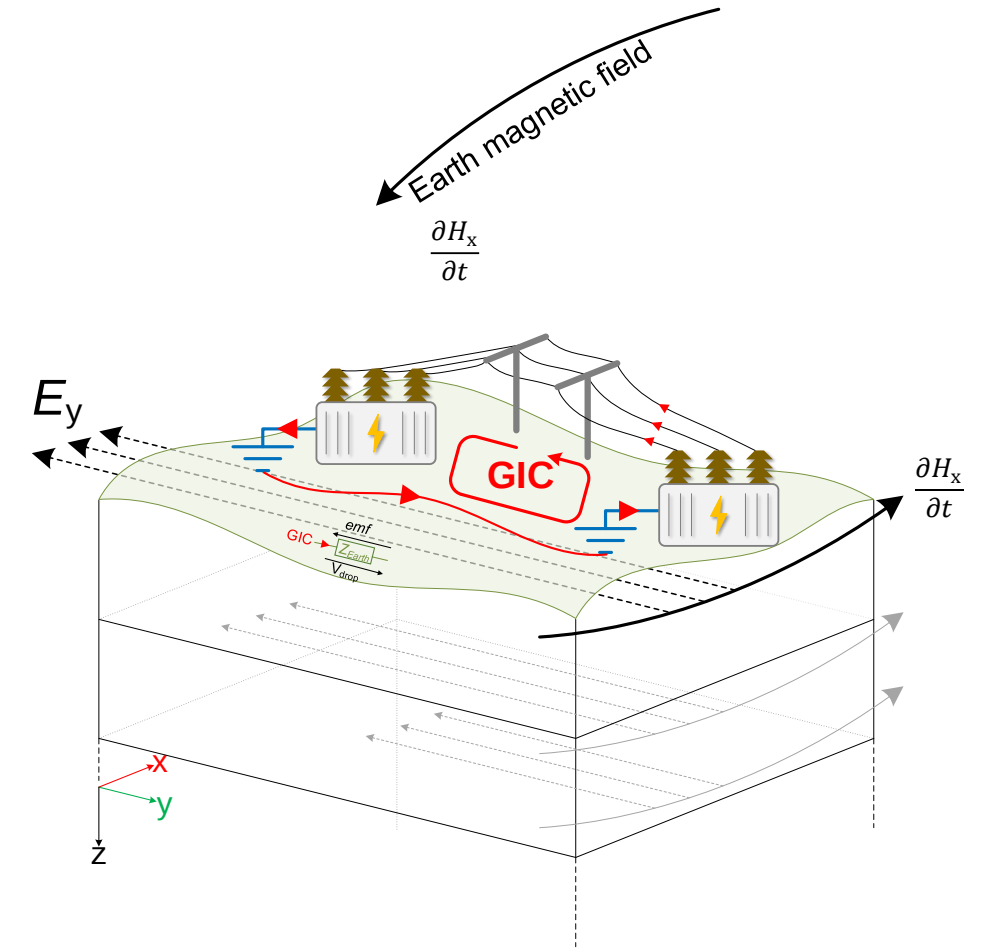
Source:
https://www.nasa.gov/multimedia/imagegallery/image_feature_2422.html

Solar Eruption on the Sun...



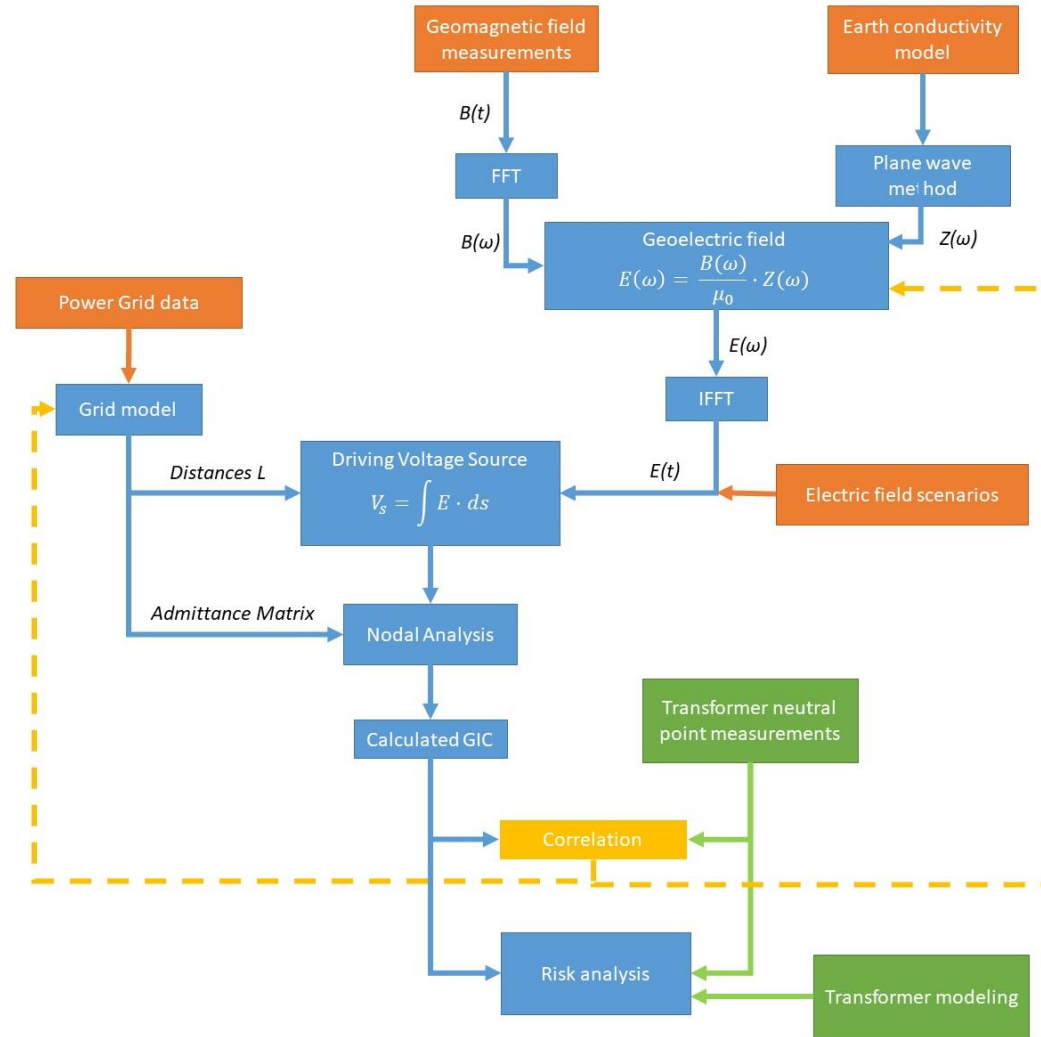
Source: <https://svs.gsfc.nasa.gov/20097>

causes Earth magnetic field variations...

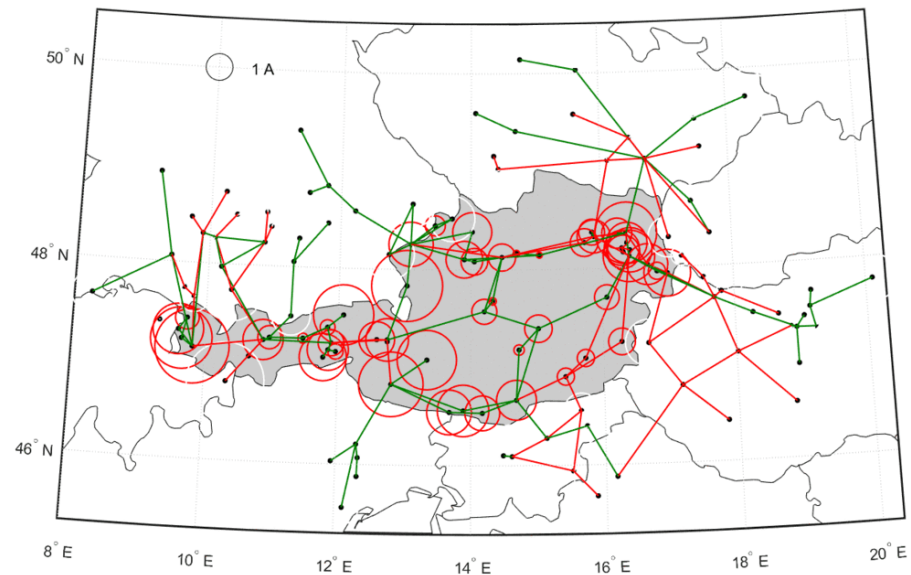


causing an electromotive force.

Power Grid Calculations



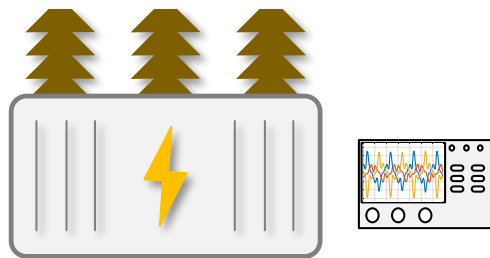
Power Grid Calculations



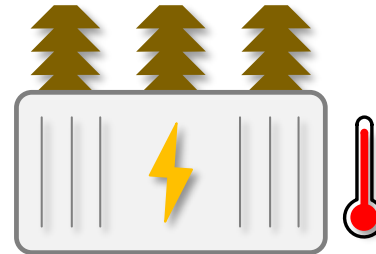
Free download: https://github.com/P-Schachinger/LFC_simulator

Effects on Transformers

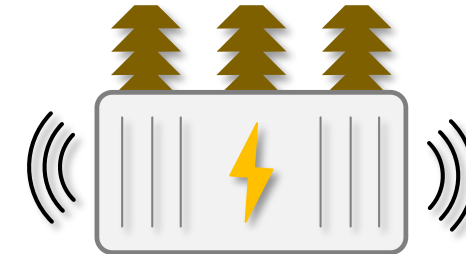
Effects of DC on transformers



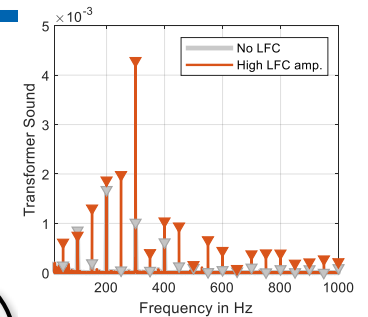
Half-Cycle Saturation & Harmonics



Heating



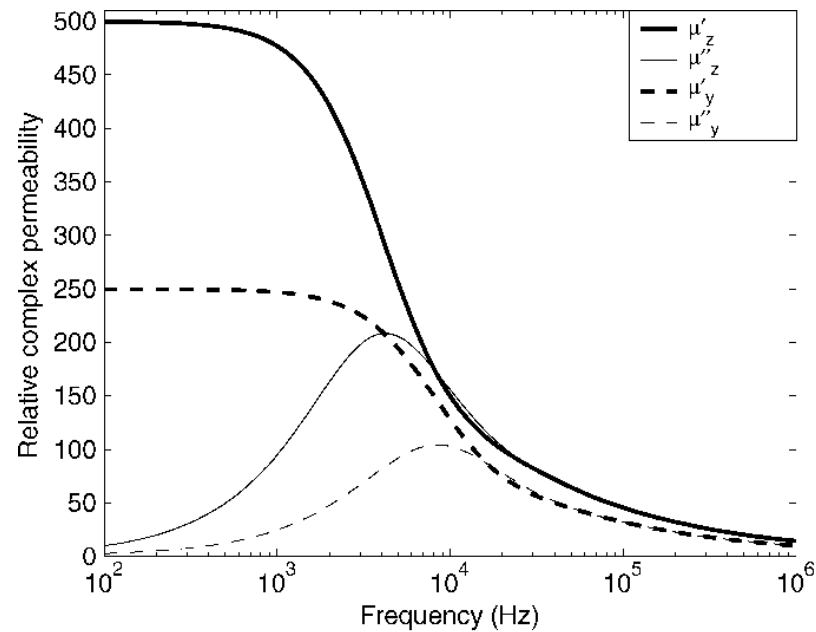
Transformer Sound



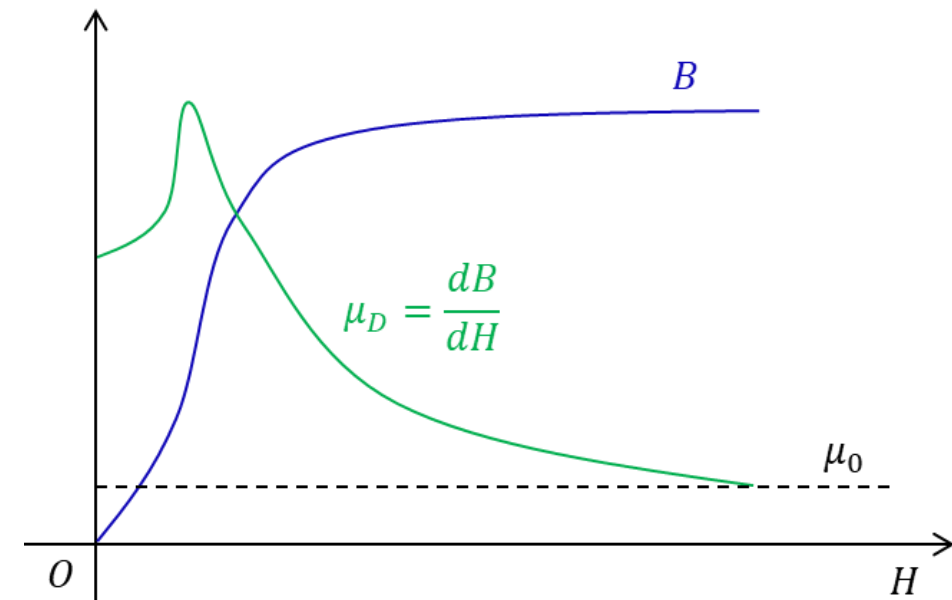
Transformer behaviour under DC bias (I)

$$\mu_r = f(f)$$

$$\mu_r = f(H)$$



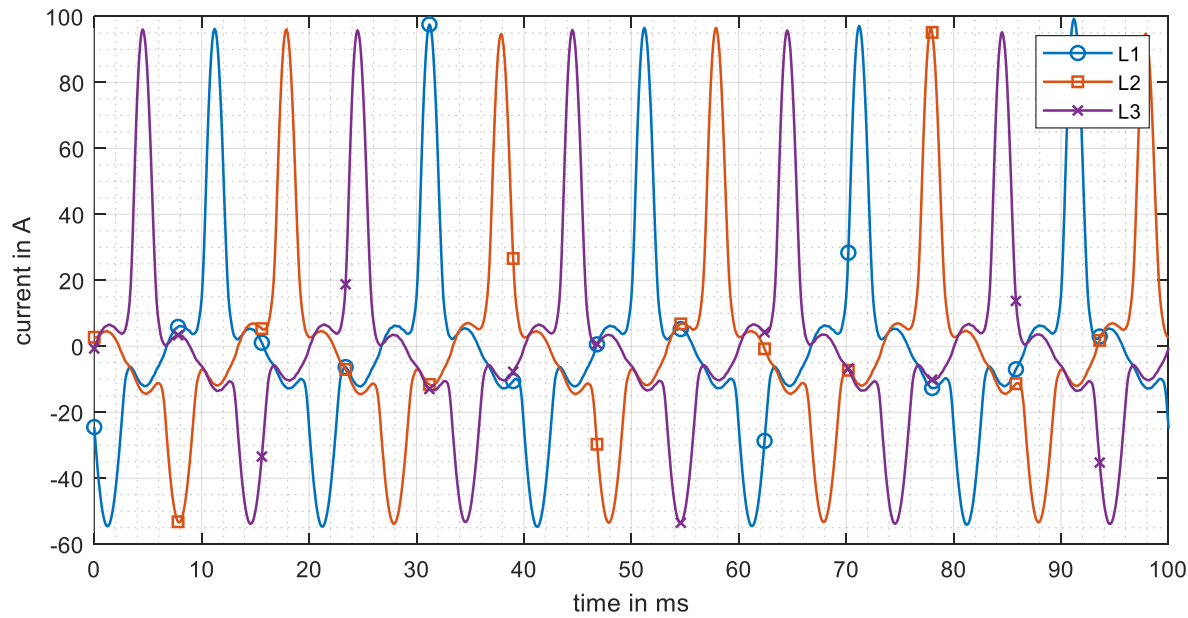
K. G. N. B. Abeywickrama, T. Daszczyński, Y. V. Serdyuk and S. M. Gubanski, "Determination of Complex Permeability of Silicon Steel for Use in High-Frequency Modeling of Power Transformers," in *IEEE Transactions on Magnetics*, vol. 44, no. 4, pp. 438-444, April 2008, doi: 10.1109/TMAG.2007.914857.



Liu, L., "How the B-H Curve Affects a Magnetic Analysis (and How to Improve It)," November 26th 2019, <https://www.comsol.com/blogs/how-the-b-h-curve-affects-a-magnetic-analysis-and-how-to-improve-it/>

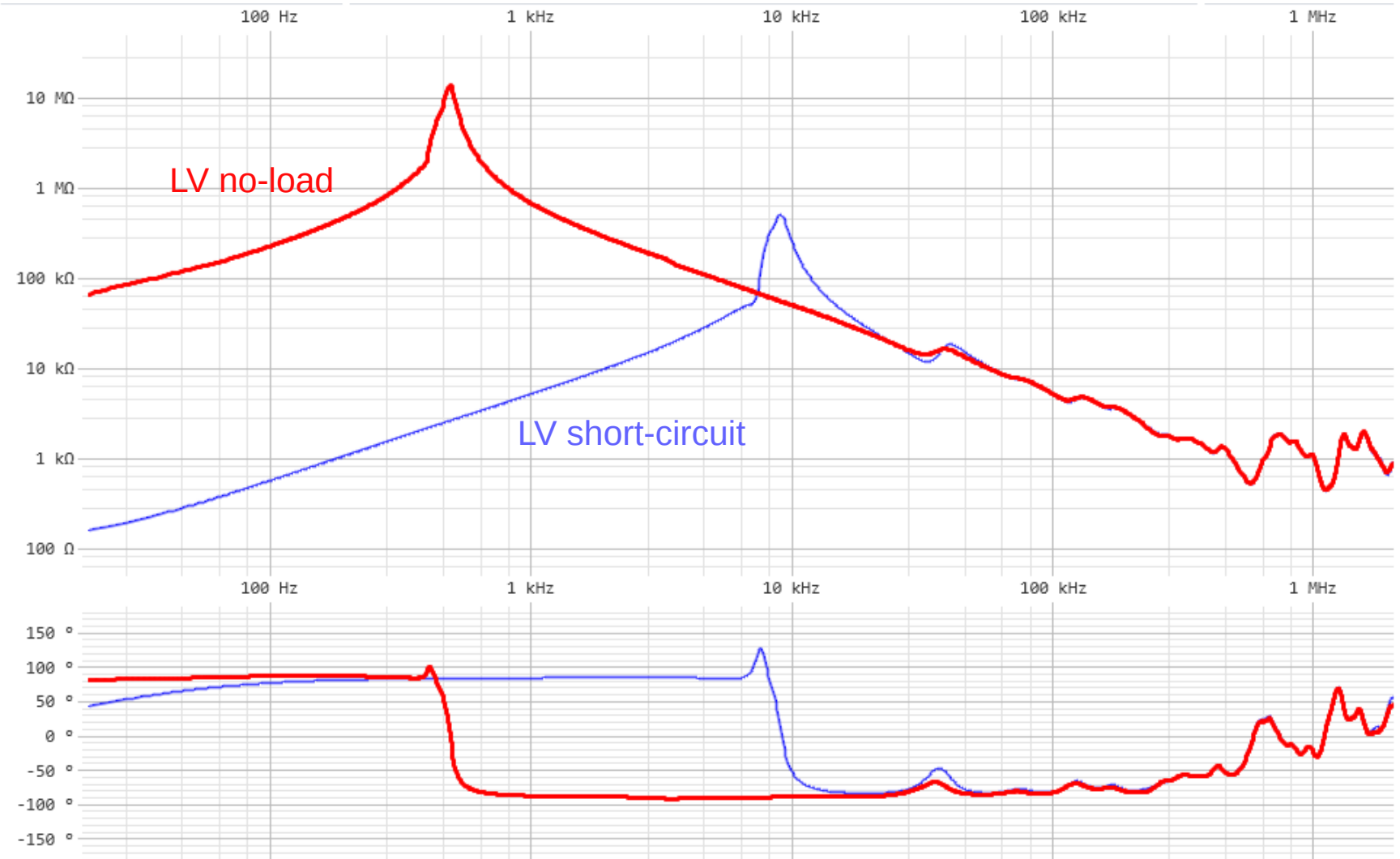
Transformer behaviour under DC bias (II)

- 1) DC/GIC bias causes transformer saturation $\rightarrow \mu_r = f(H)$
- 2) Transformer saturation cause harmonics $\rightarrow \mu_r = f(f)$



2 x 50 kVA transformers back-to-back with 1.5 A DC via HV neutral

Sweep Frequency Response Analysis



Power Transformer Hysteresis Measurement

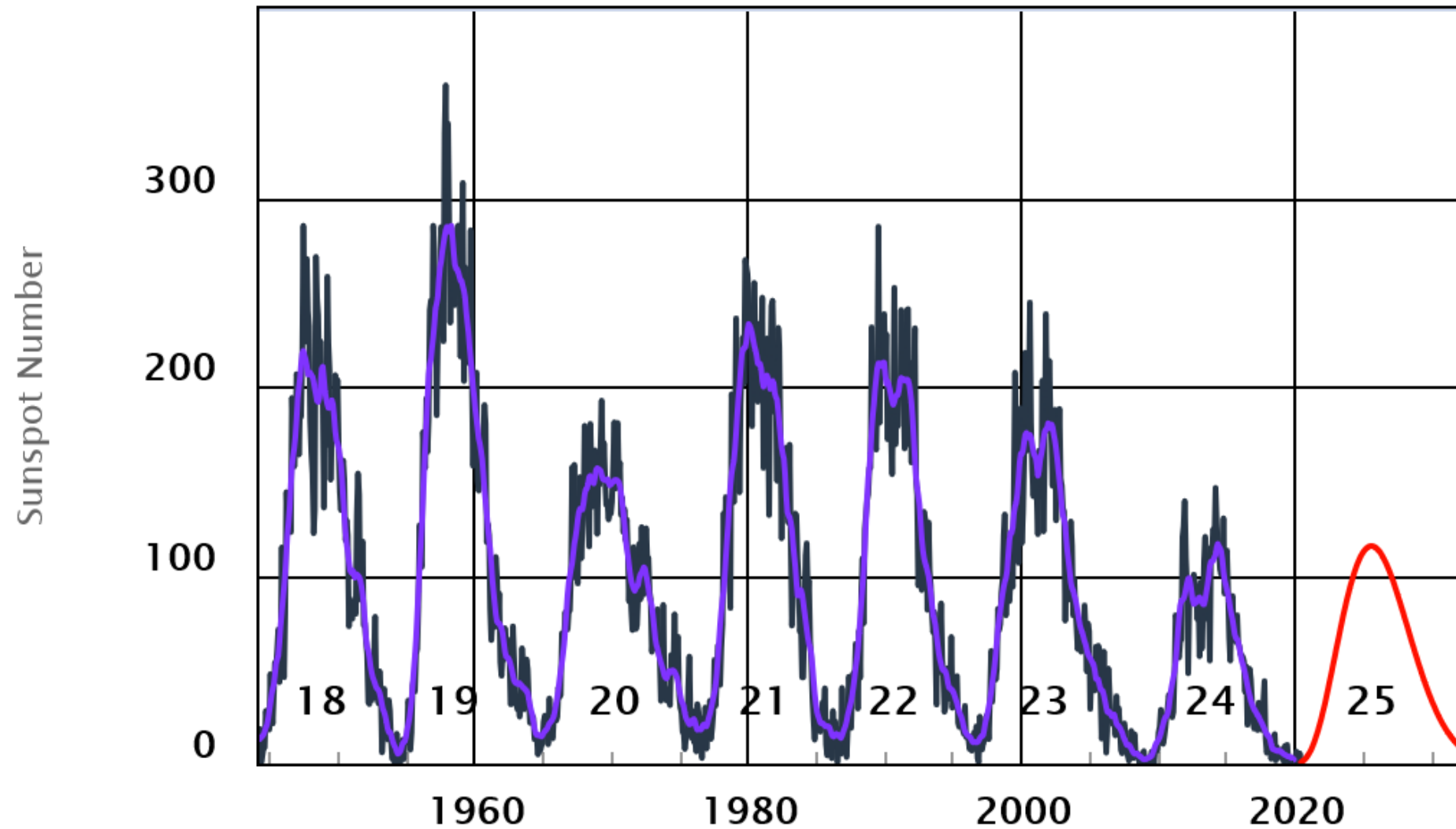
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April 7th, 2022

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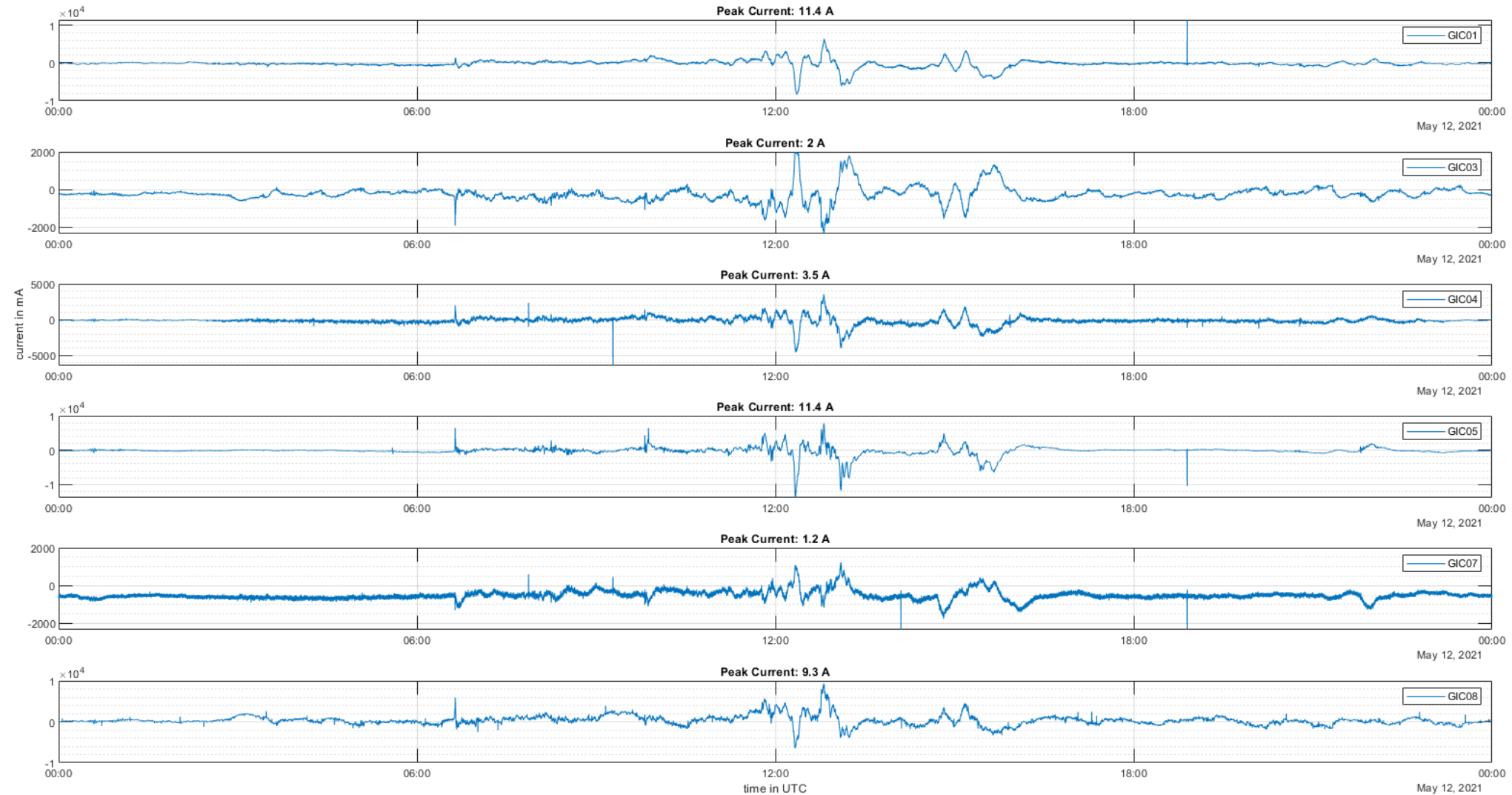
Dennis Albert | dennis.albert@tugraz.at | +43 (0) 316 873 7568

Solar Cycle

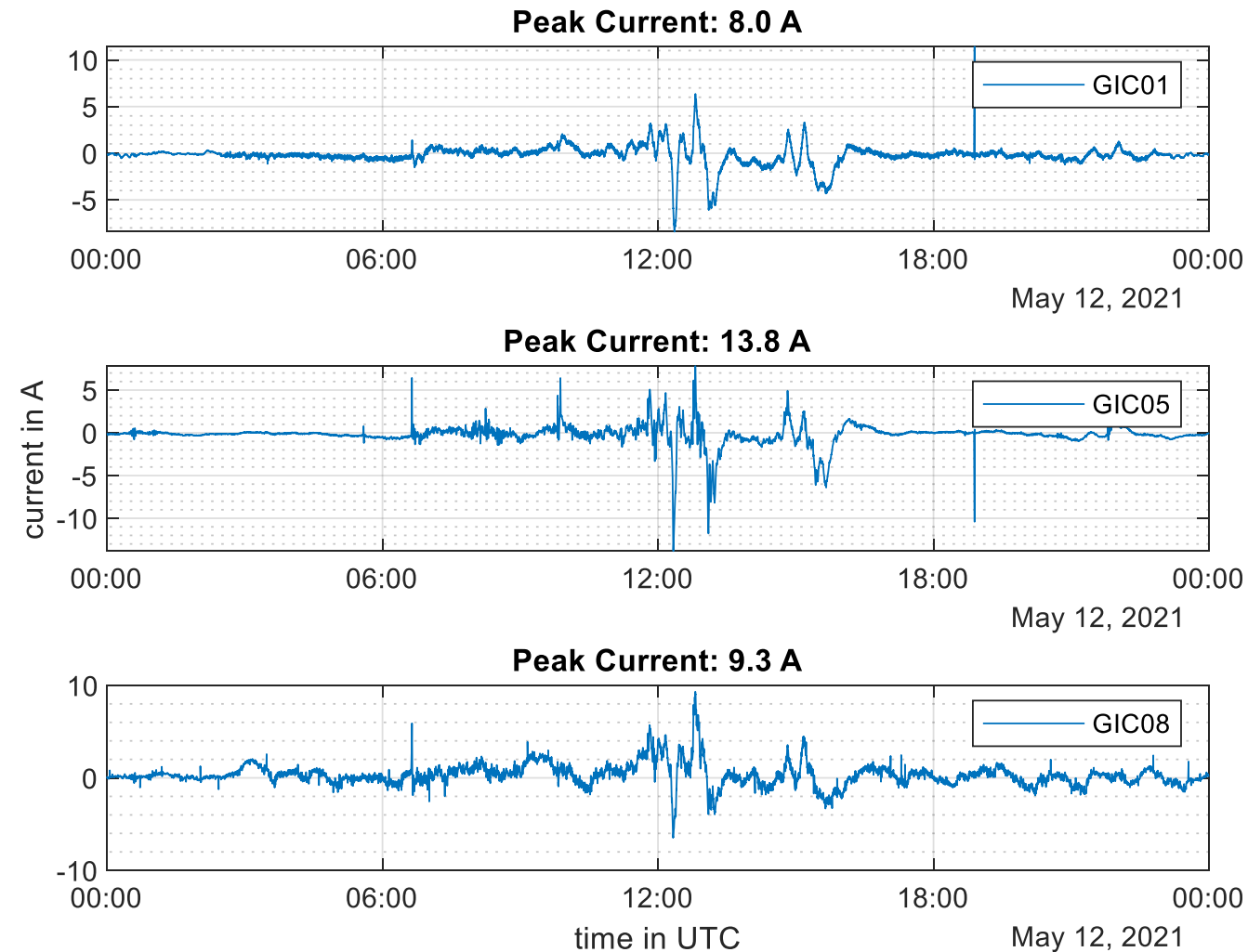


credit: <https://www.swpc.noaa.gov/news/new-solar-cycle-progression-plots-replace-legacy-plots>

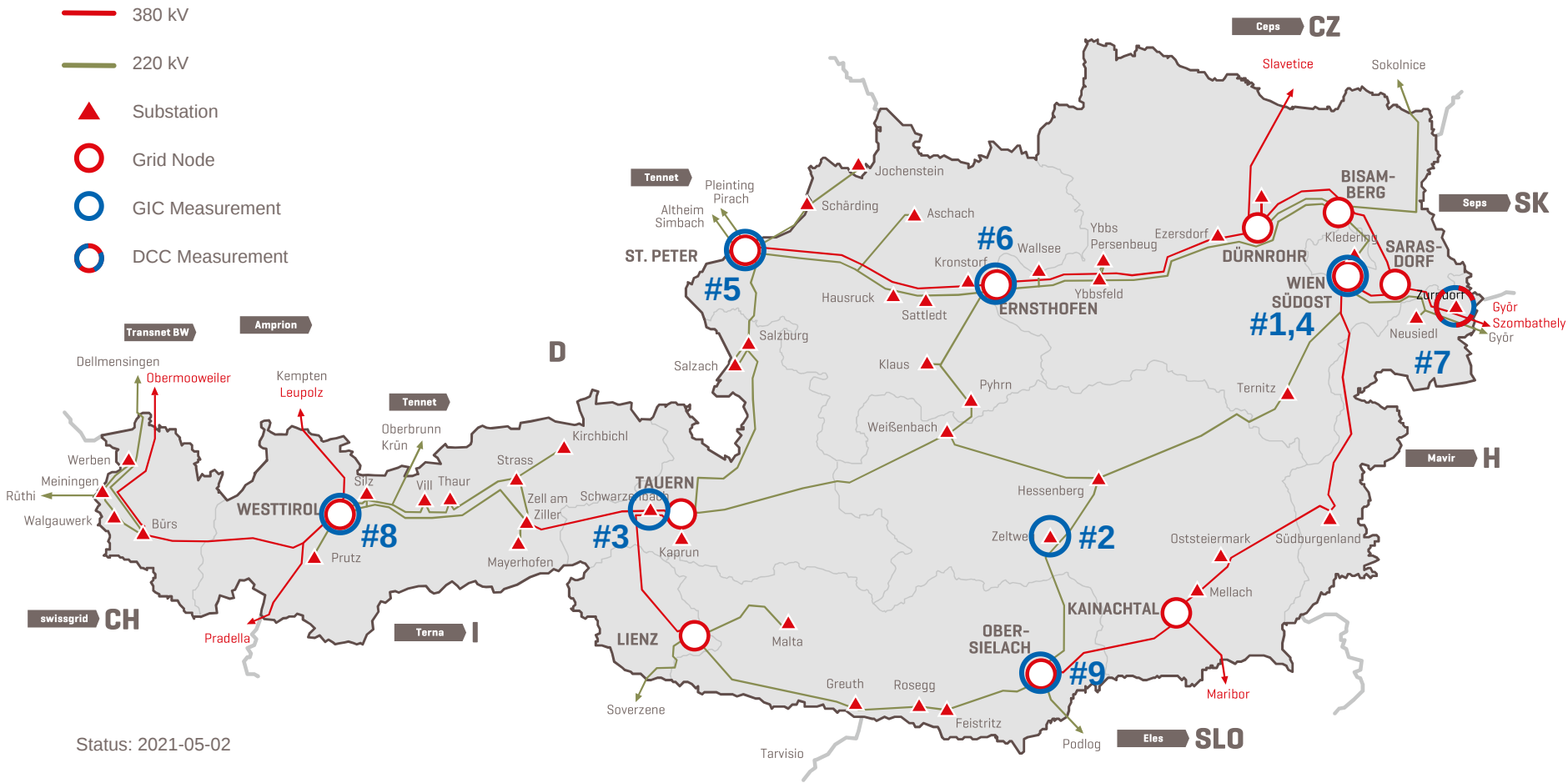
Solar Storm May 12th 2021 (I)



Solar Storm May 12th 2021 (II)



Measurement Locations



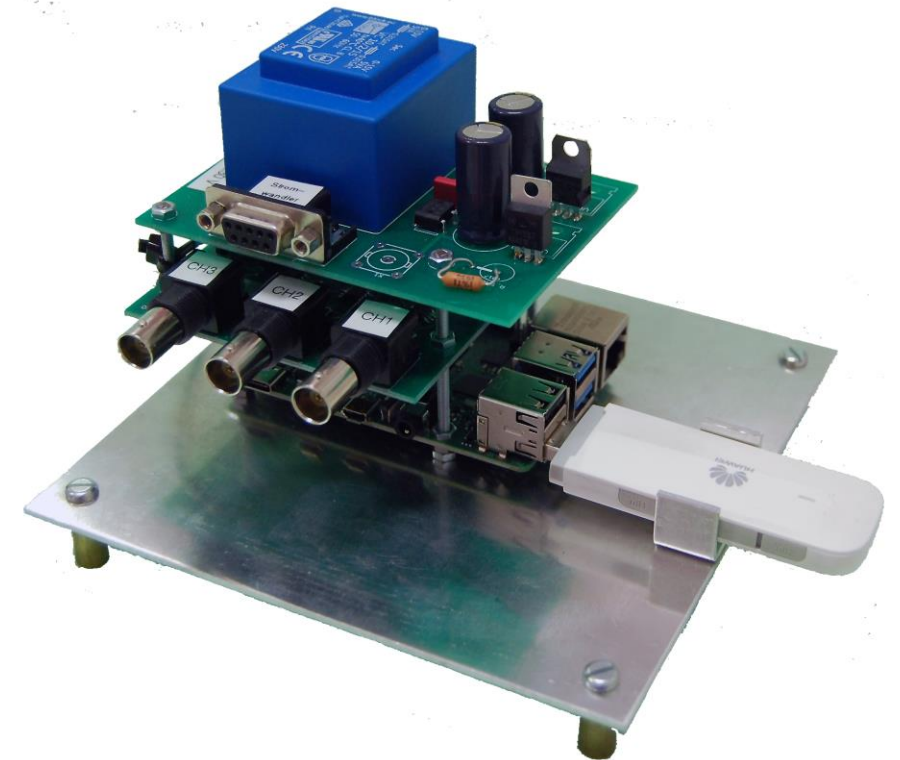
Sternpunktstrommesssystem



220 kV-Sternpunkt Messung

Measurement Electronic

- Measurement Range: $\pm 25 A_{DC}$
- Low-Pass Filter: 0,7 Hz @ -3 dB
- Voltage Output: $\pm 2,083 V$
- Resolution: $\pm 1 mA$
- Accuracy: 2 % $\pm 1mA$ @ $\pm 25 A_{DC}$
- Burden: 50 Ω (0,1 % Genauigkeit, 2 W)
- Recording: Raspberry Pi 4



Vienna Subway

