Decentralized grid control

Prof. Dr. Eberhard Waffenschmidt

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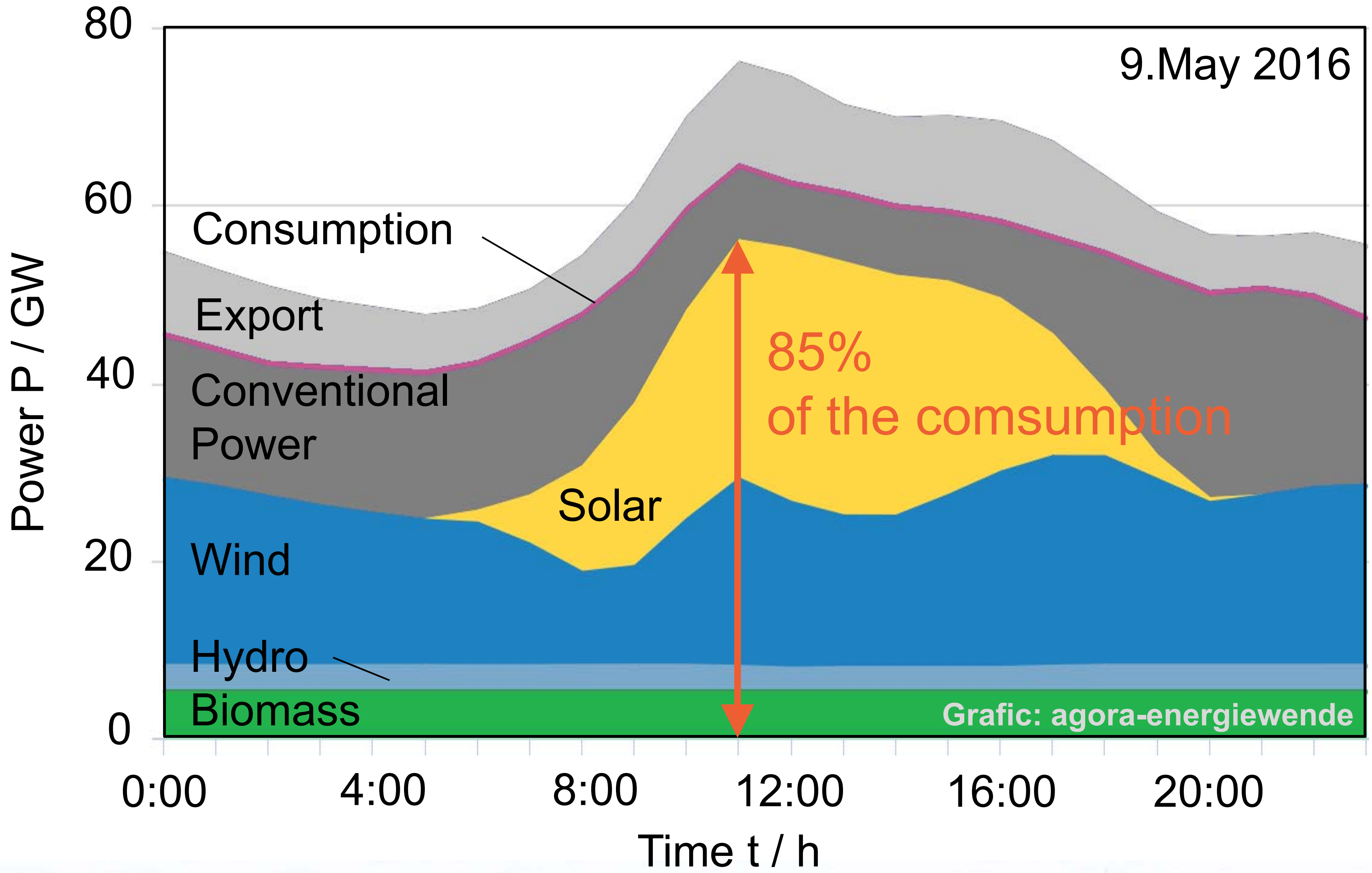
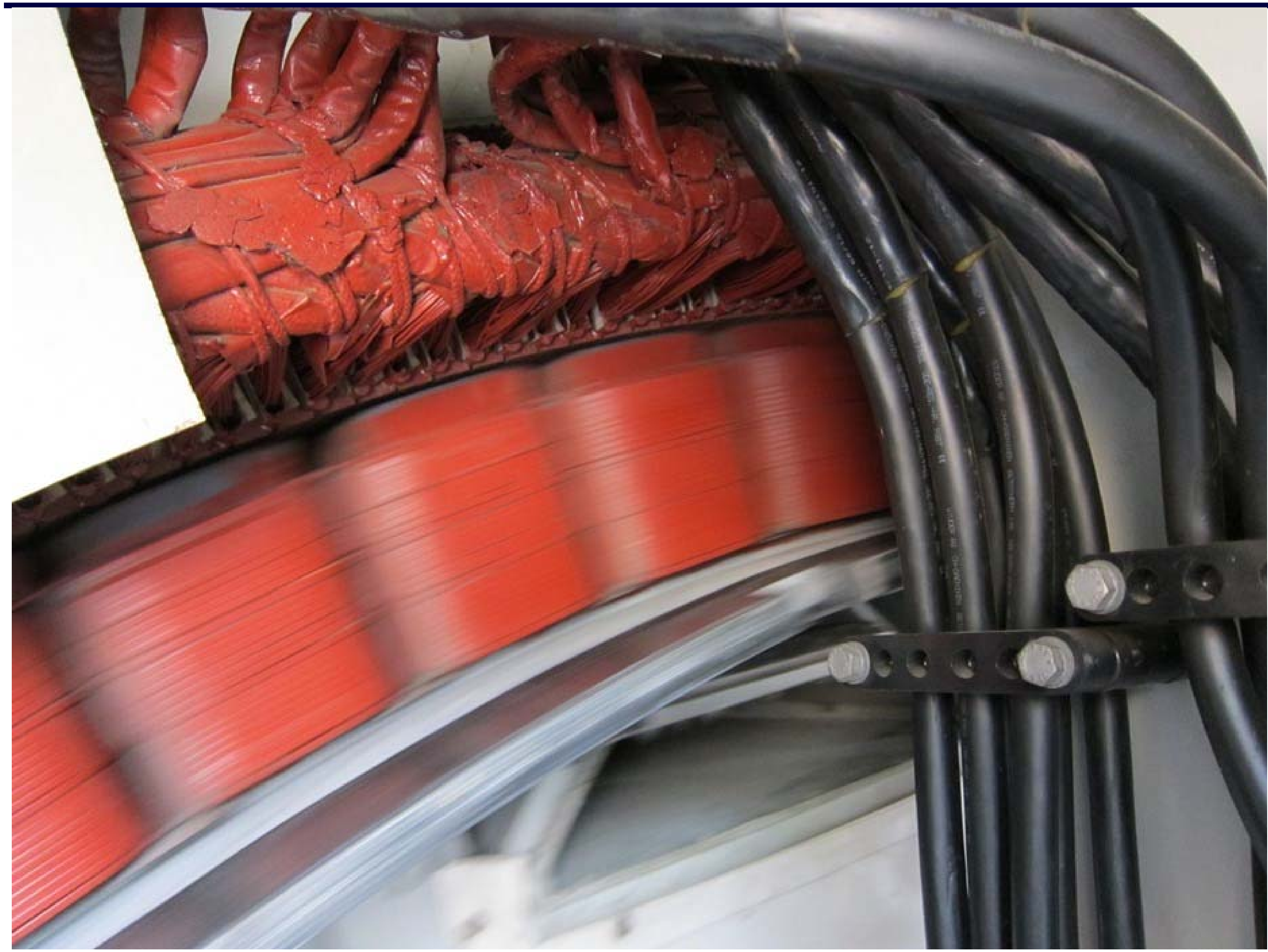
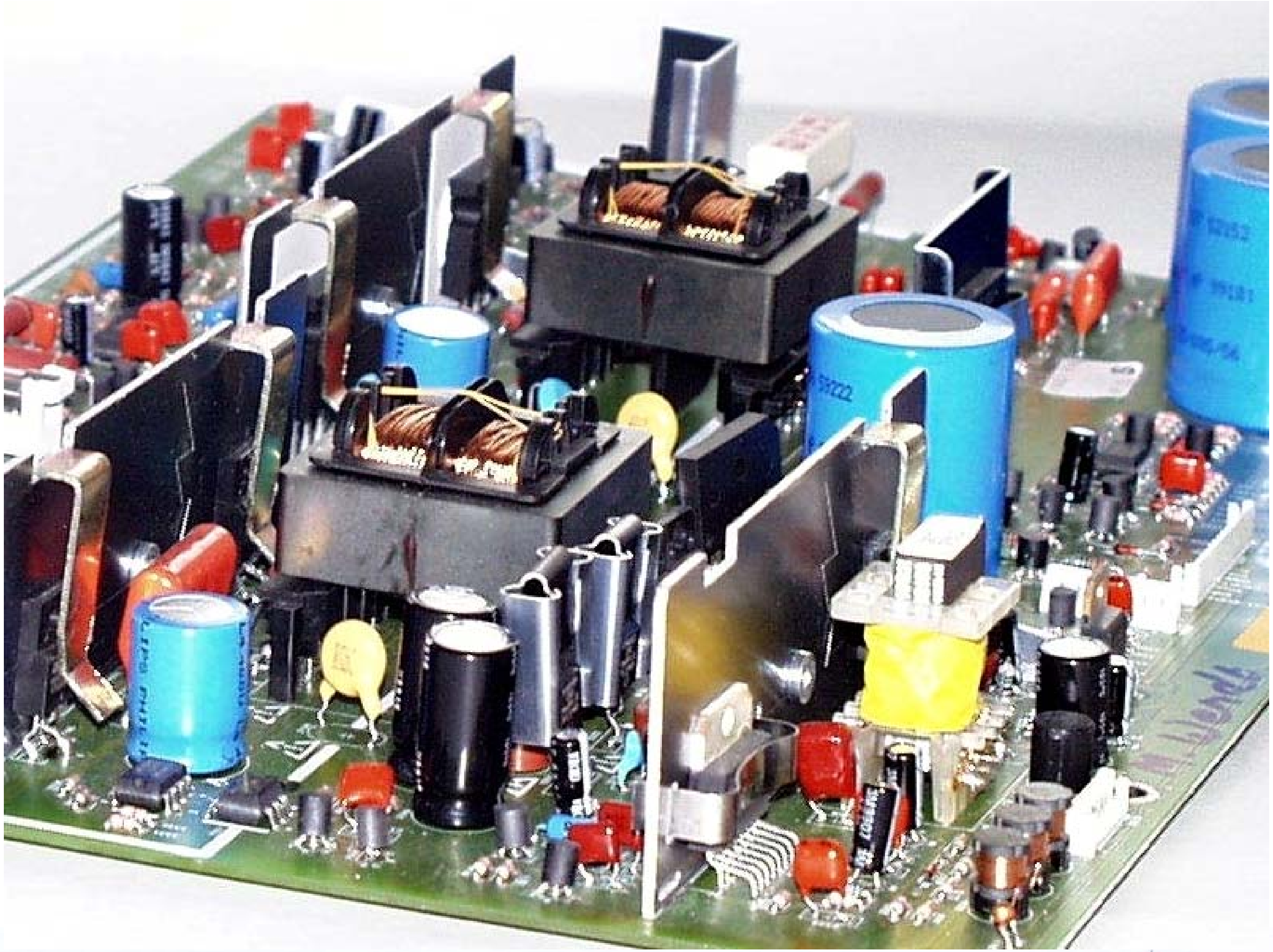
Sometimes 85% RE in the grid



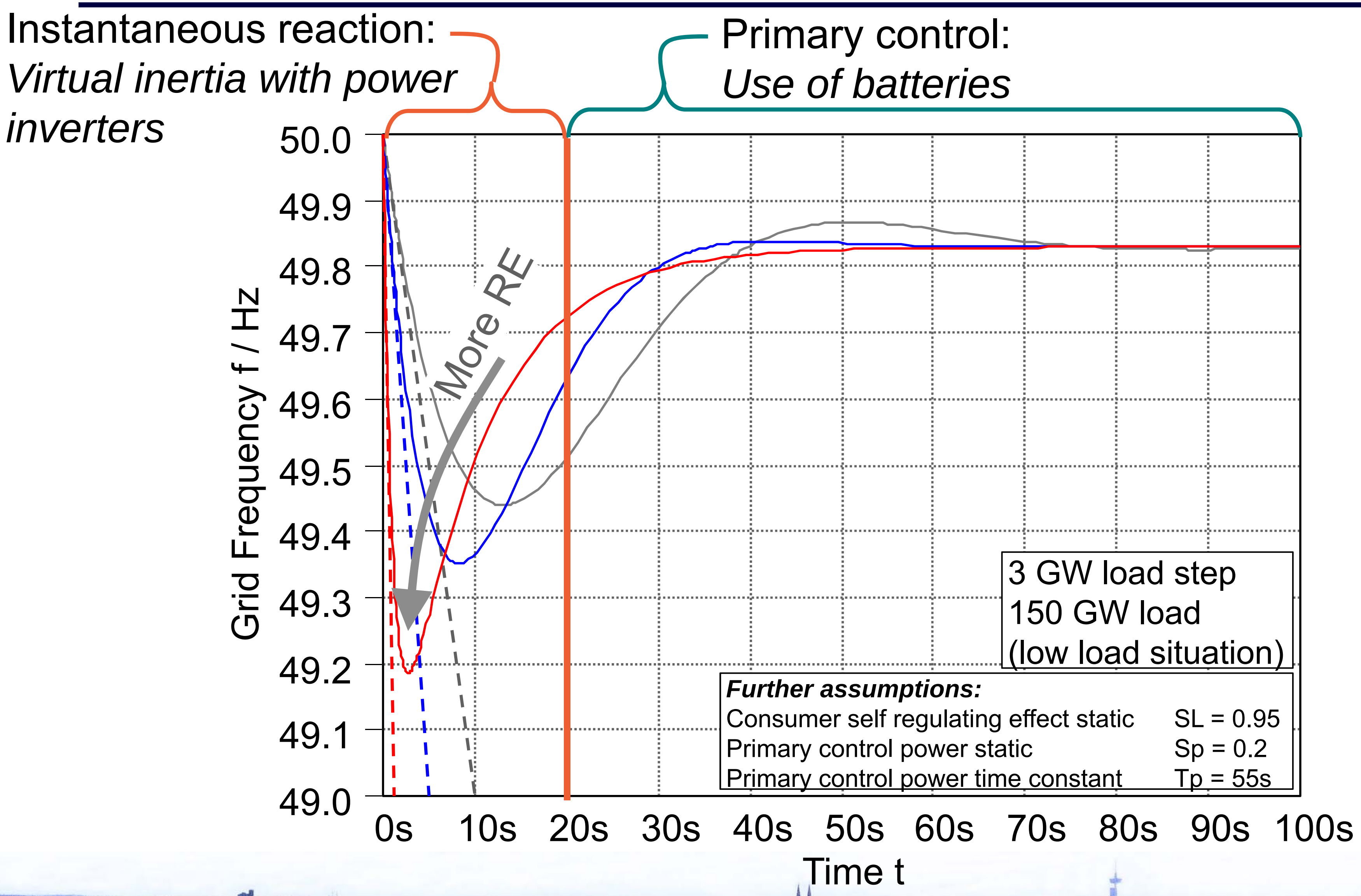
Conventional generators will be missing



Generators replaced by electronics

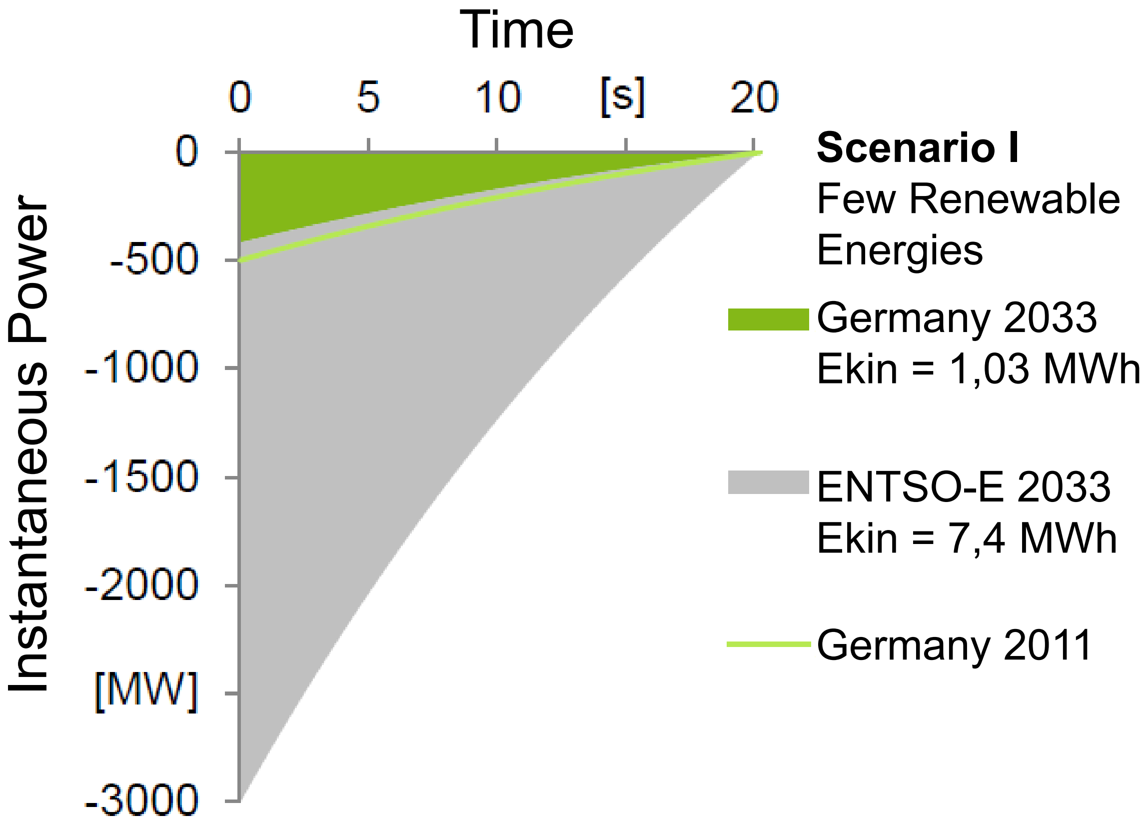


Reaction to load step



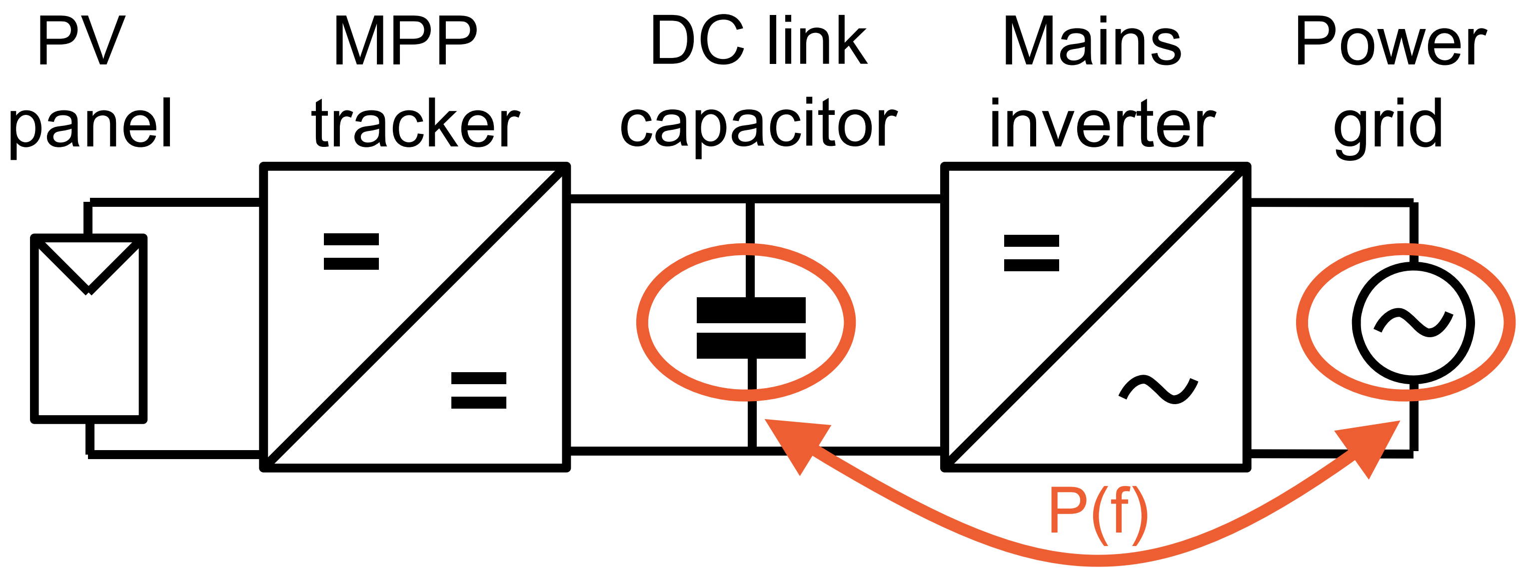
Virtual intertia
with power converters

Required Energy

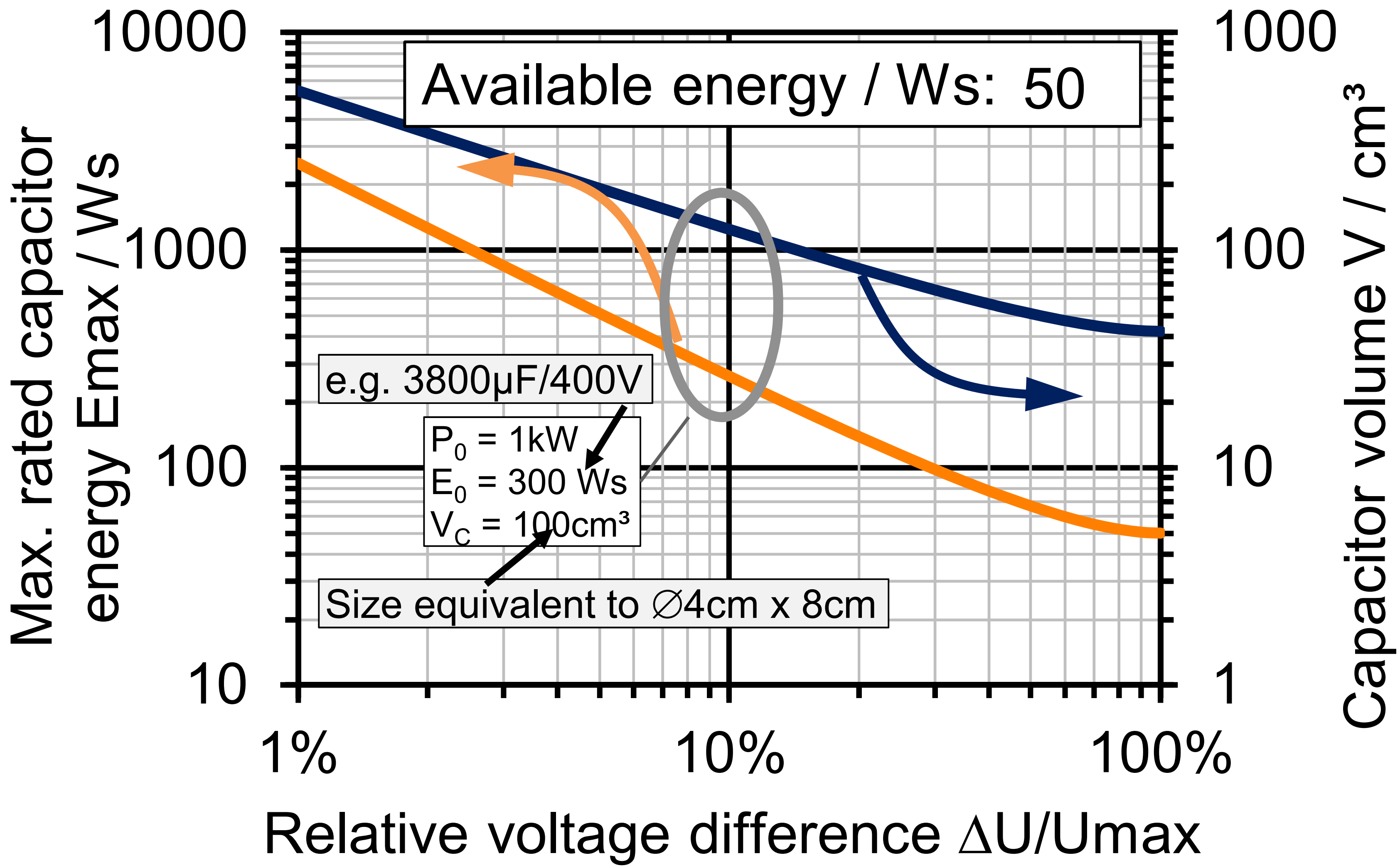


- Contribution of Germany to Instantaneous Control:
  - Energy: 3700 MWs
  - Power: 372 MW
- With feed in of 80 GW:
  - Power: 5W / kW
  - Energy:
  - 50Ws / kW

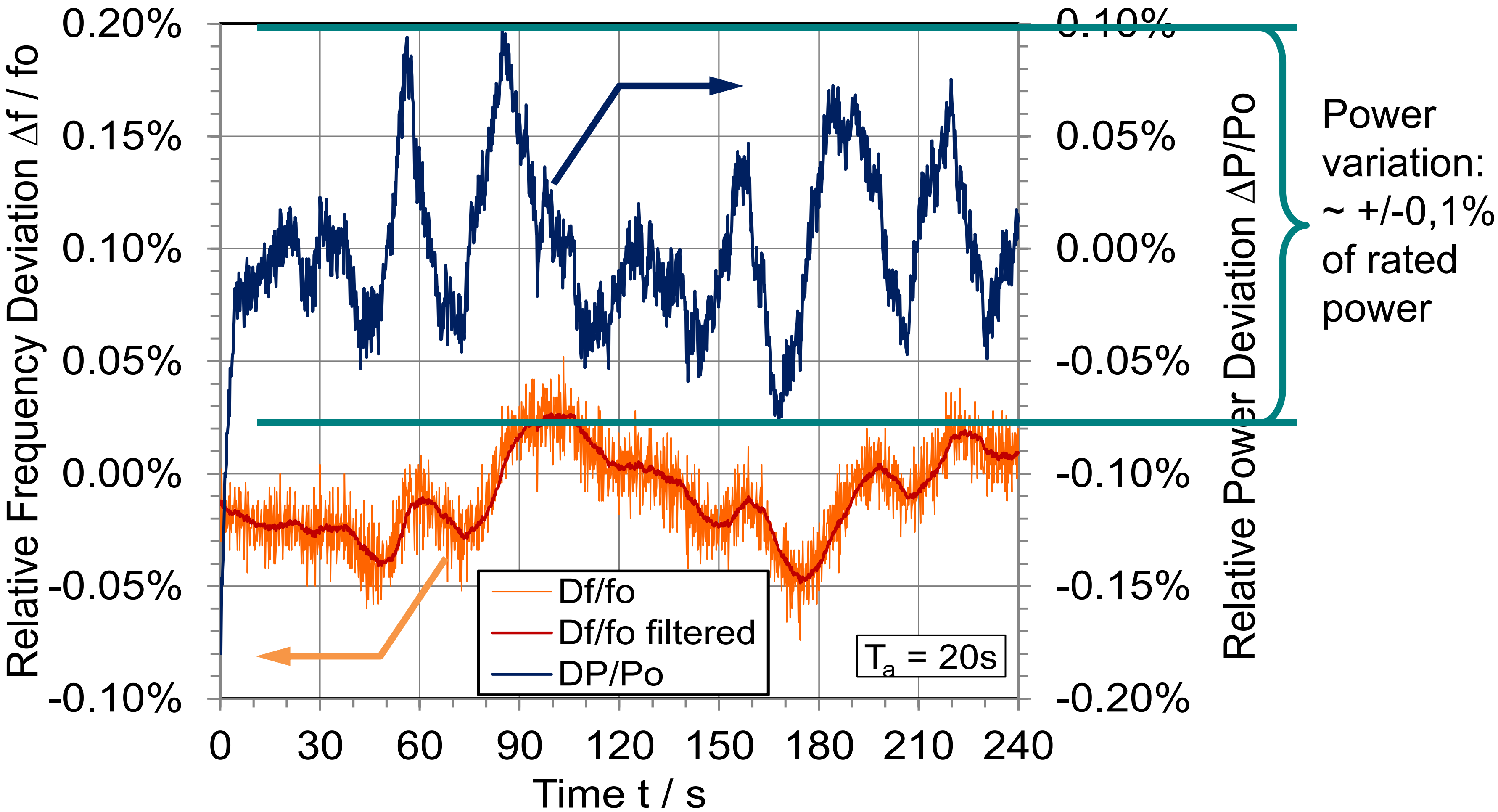
Topology for virtual inertia



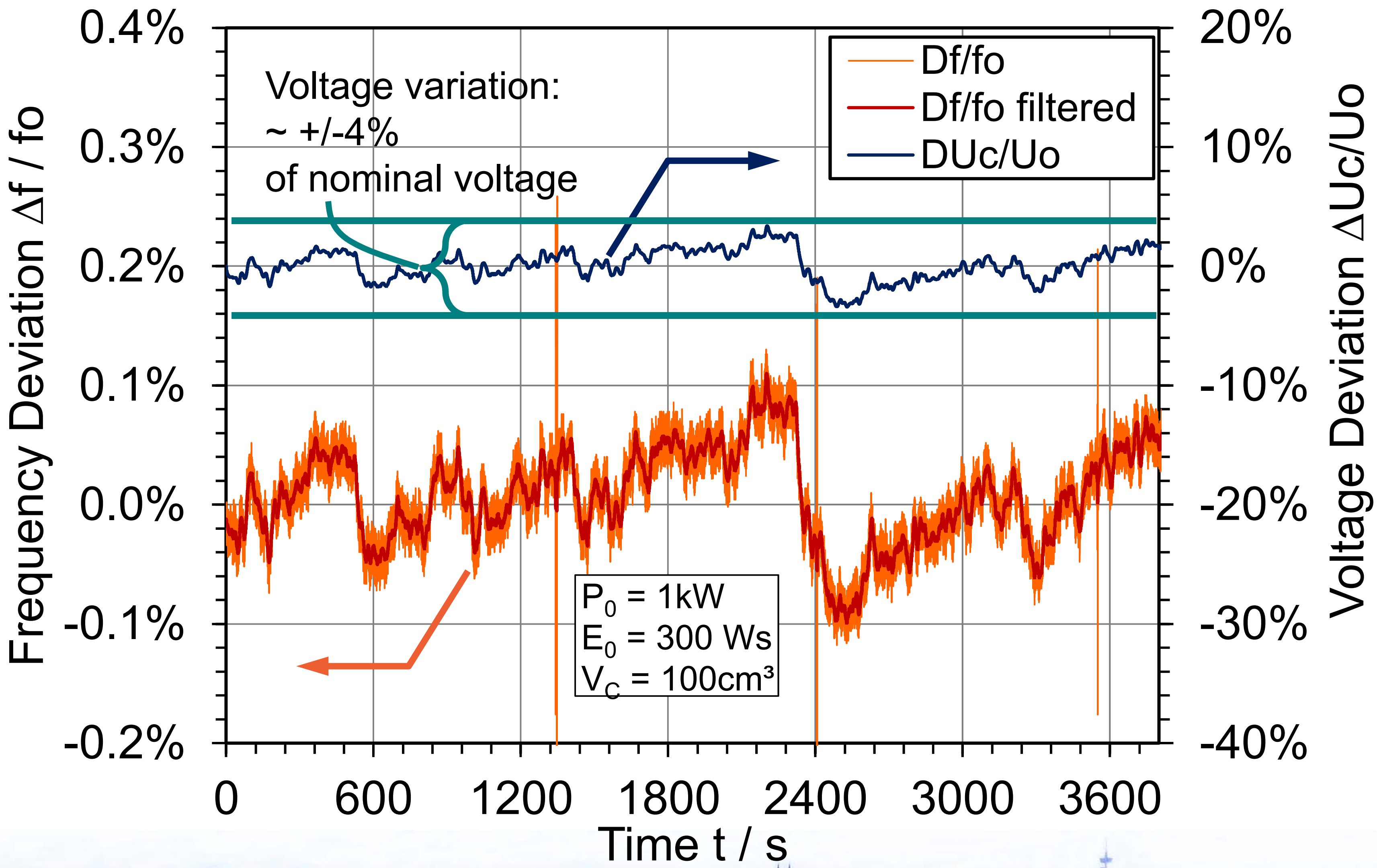
Needed capacitor size



Power variation



Variation of intermediate voltage



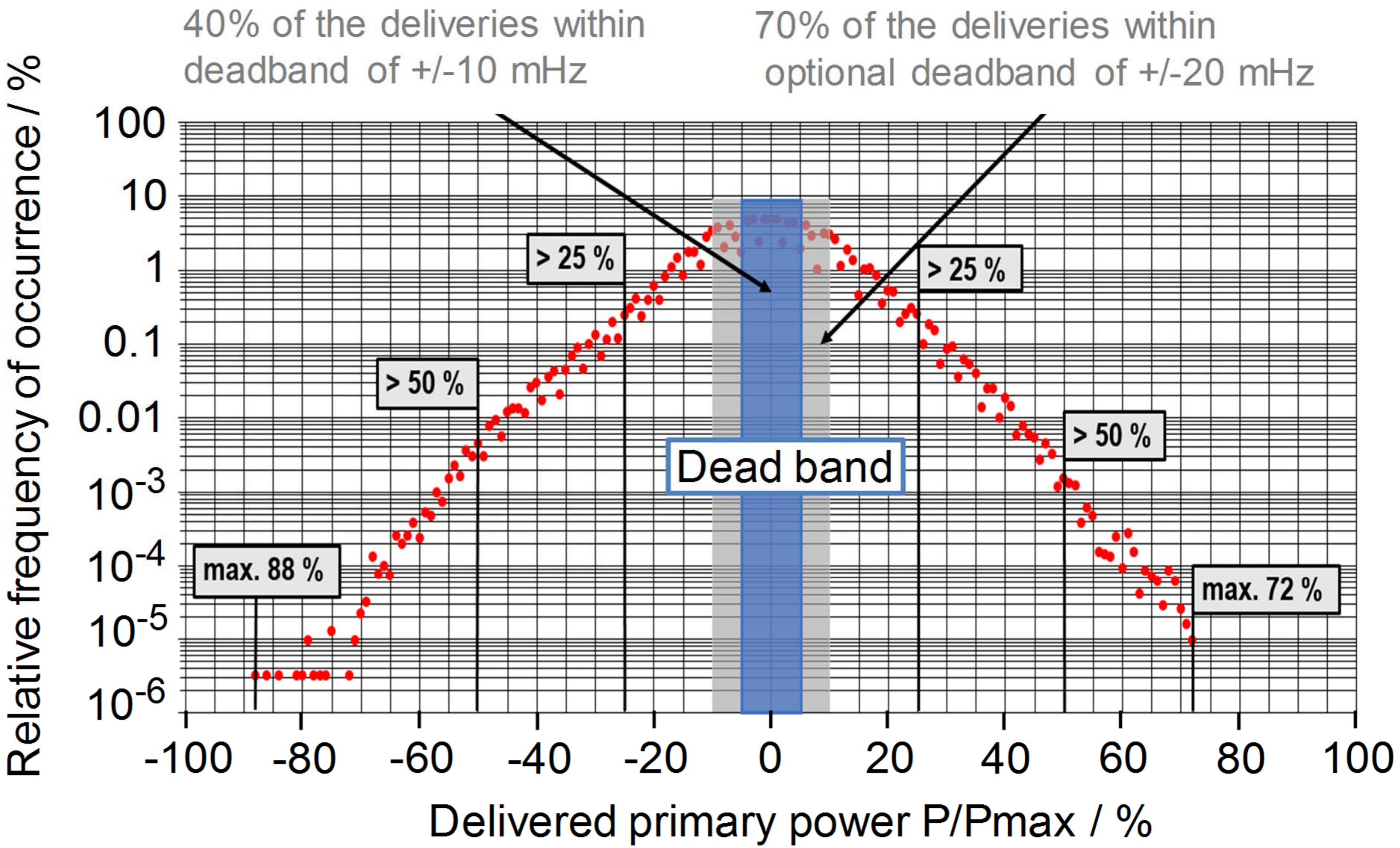
Virtual inertia with power converters

Use intermediate voltage capacitor:

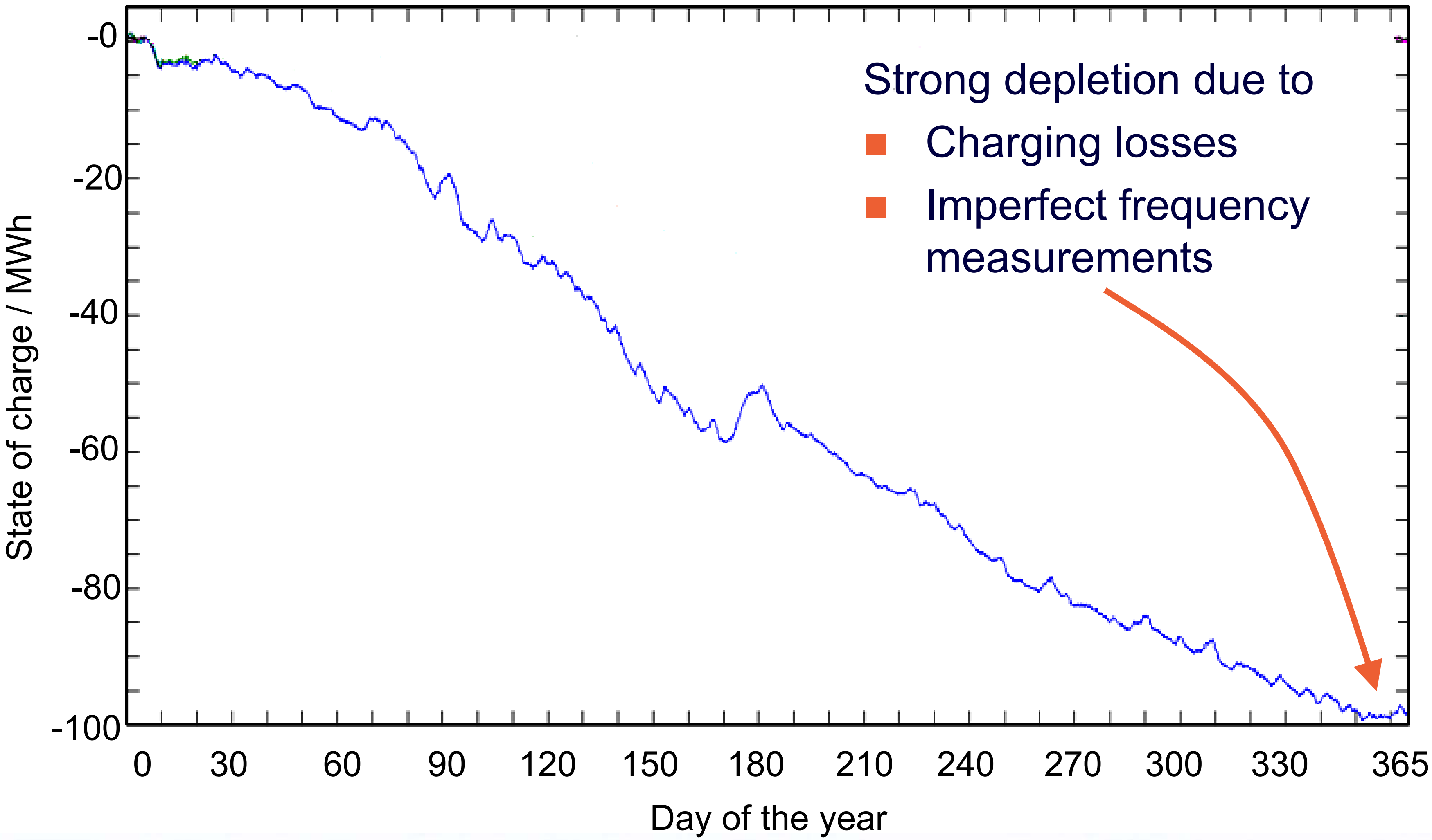
- Typical size is sufficient
- Low additional power (~ +/-0.1%)
  - No re-dimensionig necessary
- Low voltage ripple (~ +/-5%)
  - No degradation of elcap

Primary control with batteries

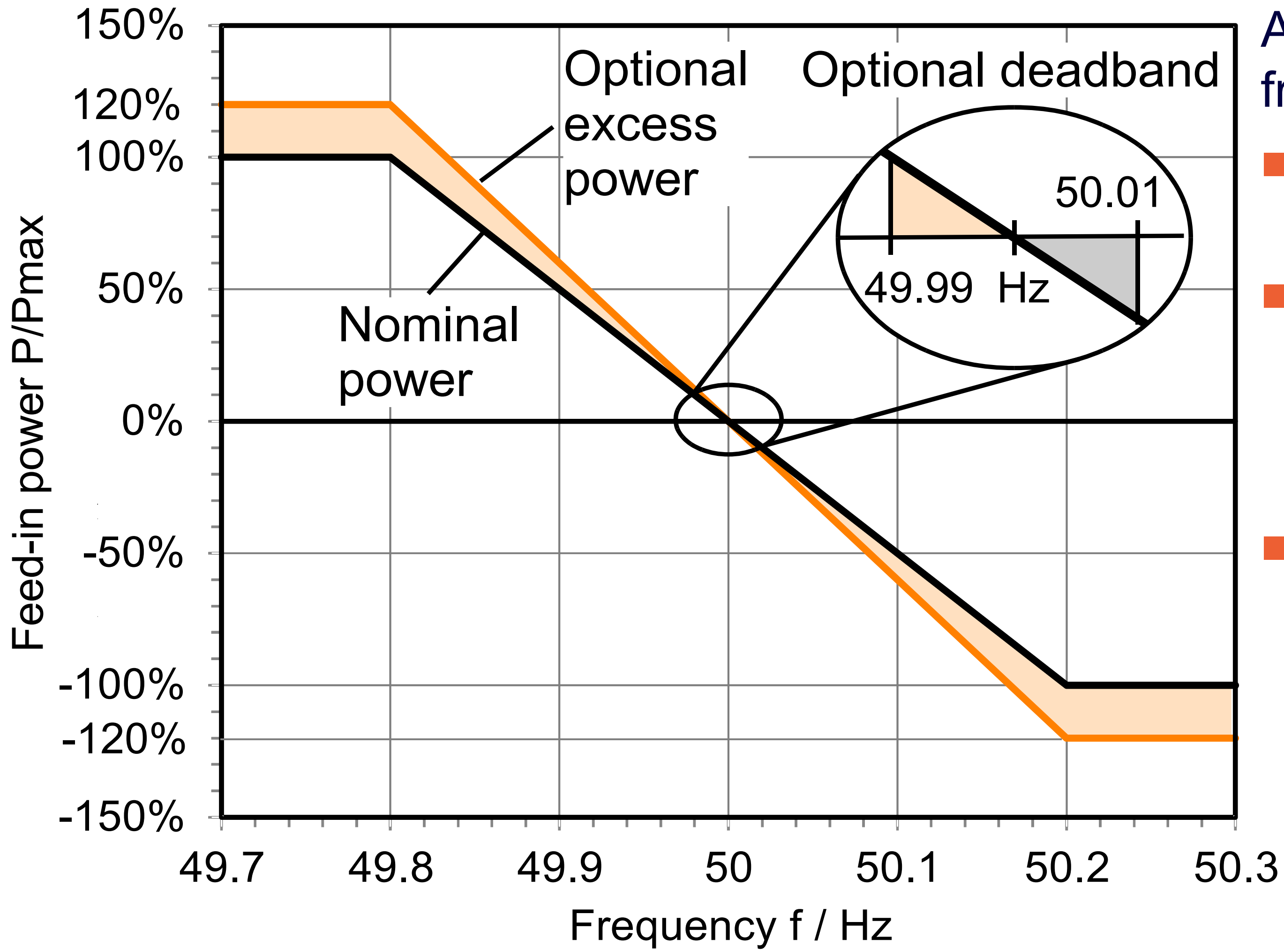
Occurrence of Primary Control Power in 2013



State of charge without measures



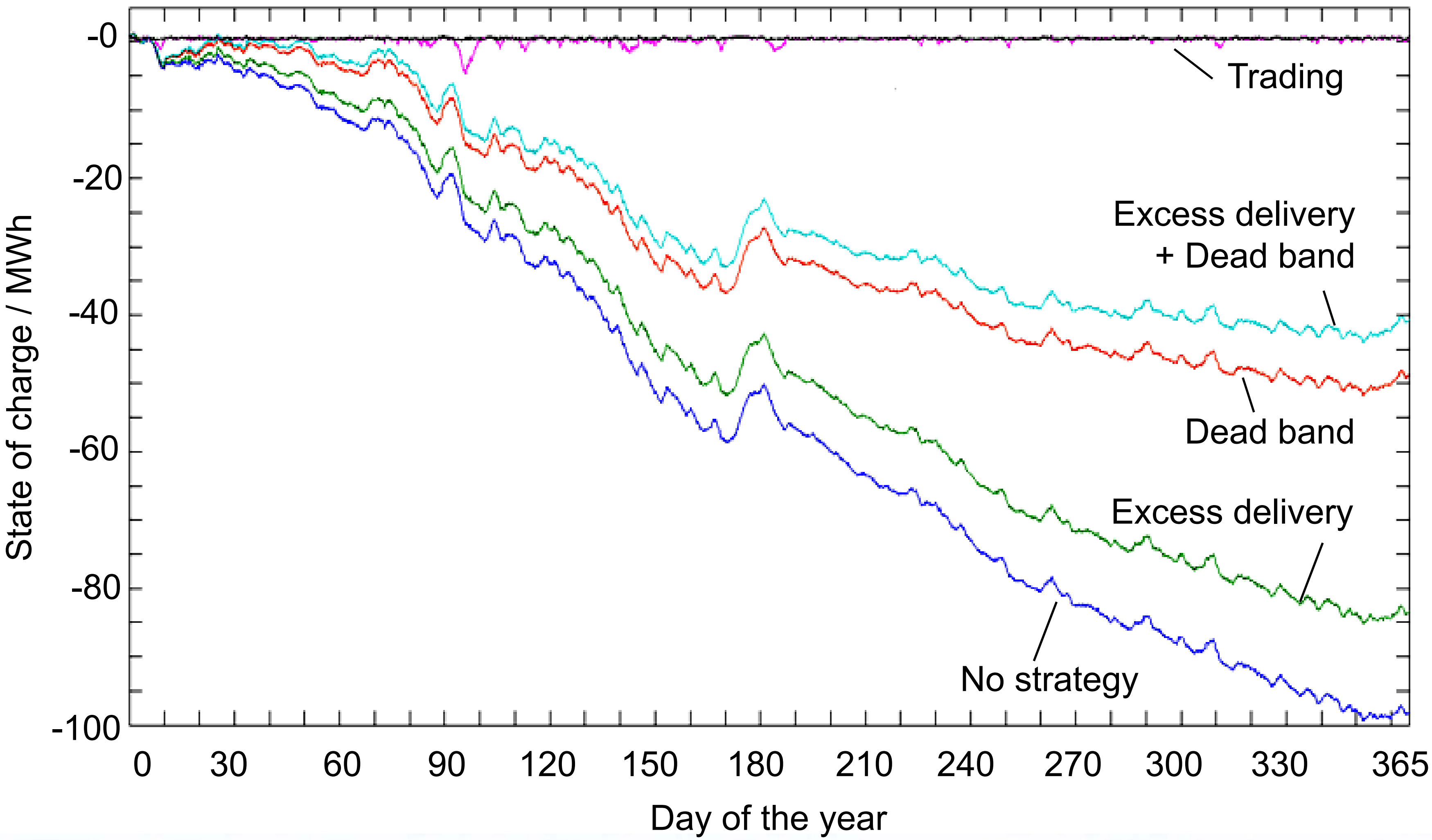
Degrees of freedom with Primary Control



Additional degrees of freedom:

- Delayed reaction: 30s to full power
- Preciseness of frequency measurement: 10 mHz
- Trading of energy

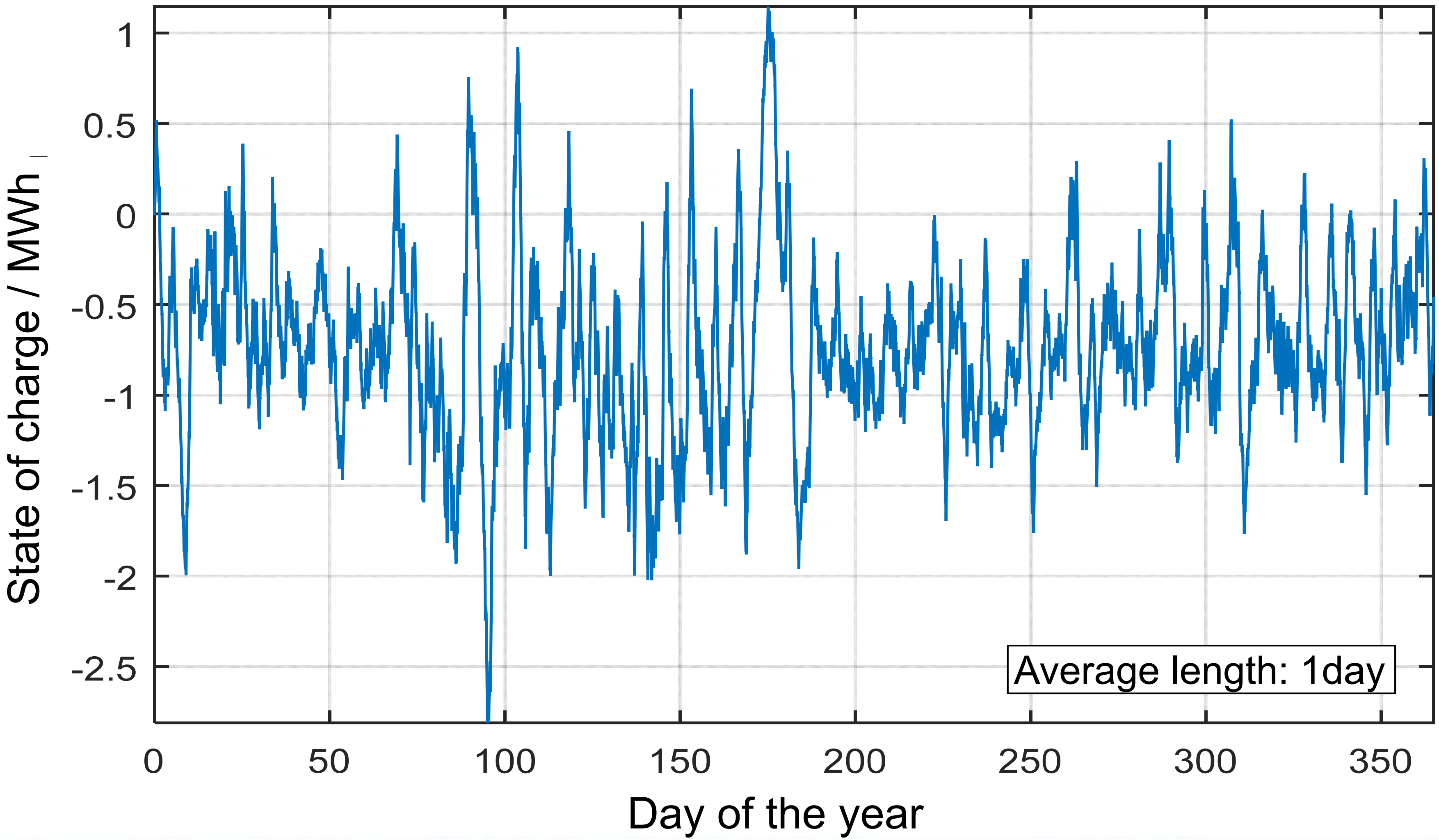
Effect of applying degrees of freedom



Preciseness of frequency measurement

- *Problem*:
  Systematic error of frequency measurement
- *Example*:
  +/-1 mHz -> +/-40 MWh per year
- *Solution*:
  Correction with running average
- *Justification*:
  Deviation from 50.000Hz compensated by power providers (synchronous time correction)

Application of running average



Primary control with batteries

- *Problem*:
  Strong depletion due to
  - Charging losses
  - Imprecise frequency measurements
- *Solution*:
  Use degrees of freedom
  - Excess delivery
  - Deadtime
  - Frequency: Averaging
  - If anything fails: Energy trading

Conclusion

Conclusion

Grid power control with decentralized sources:

- *Virtual inertia*:
  Use intermediate voltage capacitors
  of power converters
- *Primary control*:
  Use degrees of freedom for batteries

Contact

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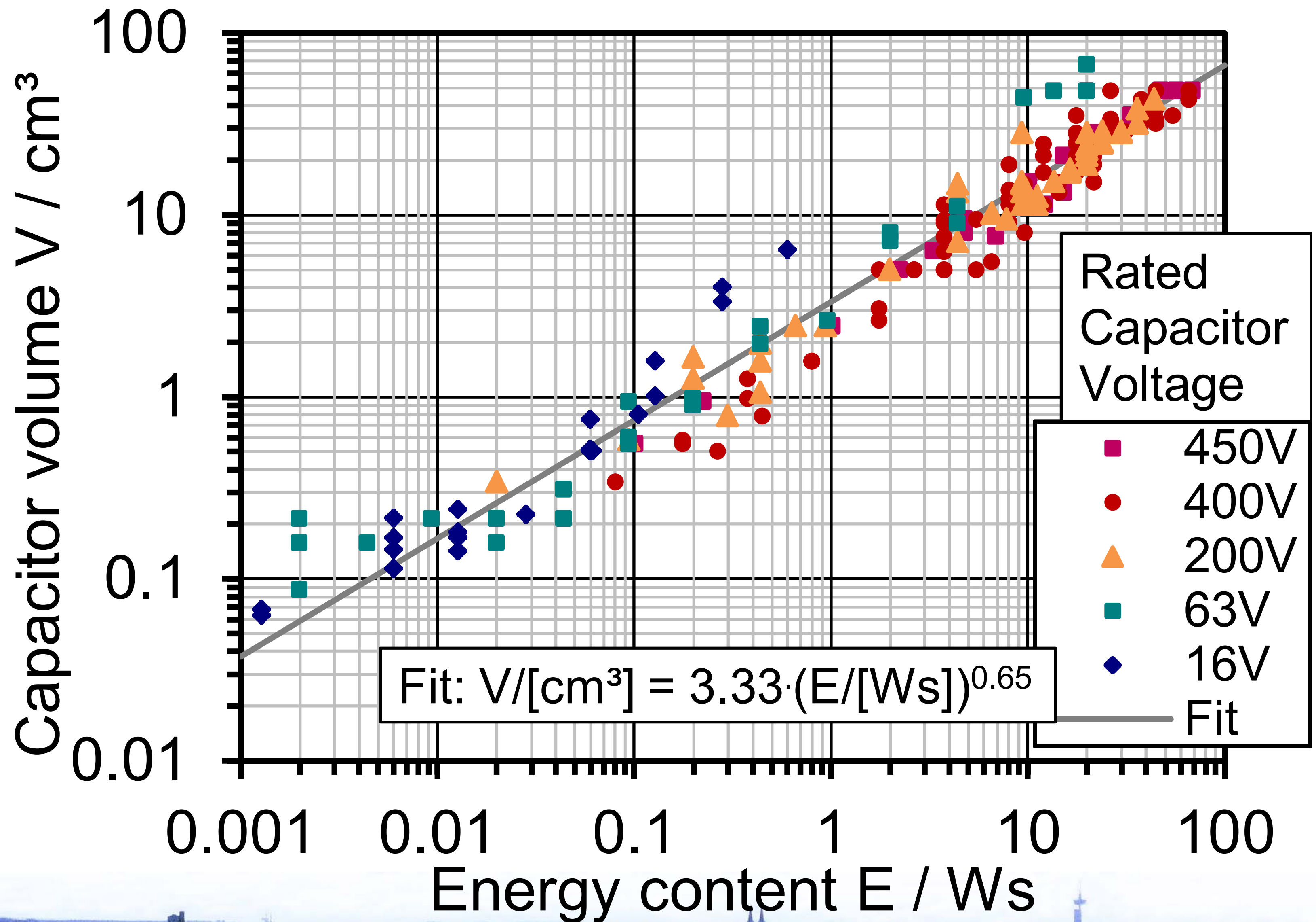
Appendix

Size of electrolytic capacitors



Voltage varitions during daily operation

Definition of time constant Ta: $$\frac{\Delta P}{P_0} = T_a \cdot \frac{d}{dt}\frac{\Delta f}{f}$$

Power into the capacitor: $$\Delta P = \Delta I \cdot U_0$$

Dependence of voltage and current: $$\Delta U_c(t) = \frac{1}{C} \cdot \int \Delta I(t)\, dt$$

Intermediate solution: $$\Delta U_c(t) = \frac{1}{C} \cdot \int \frac{P_0 \cdot T_a}{U_0} \cdot \frac{d}{dt}\frac{\Delta f}{f_0}\, dt$$

Max. energy content of capacitor: $$E_0 = \frac{1}{2} \cdot C \cdot U_0^2$$

Solution: $$\frac{\Delta U_c(t)}{U_0} = T_a \cdot \frac{1}{2} \cdot \frac{P_0}{E_0} \cdot \frac{\Delta f}{f}$$

$$\frac{\Delta U_c(t)}{U_0} \propto \frac{\Delta f}{f}$$

Δ_P = Power step
P_0 = Power in the grid
Δf = Frequency variatrion
f = Grid frequency
C = Capacity of the capacitor
I = Current into the capacitor
U_0 = Intermediate voltage
ΔU_c = Voltage variation at capacitor

Voltage variation at the capacitor is proportional to the frequency variation