# Virtual inertia with PV inverters using DC-link capacitors

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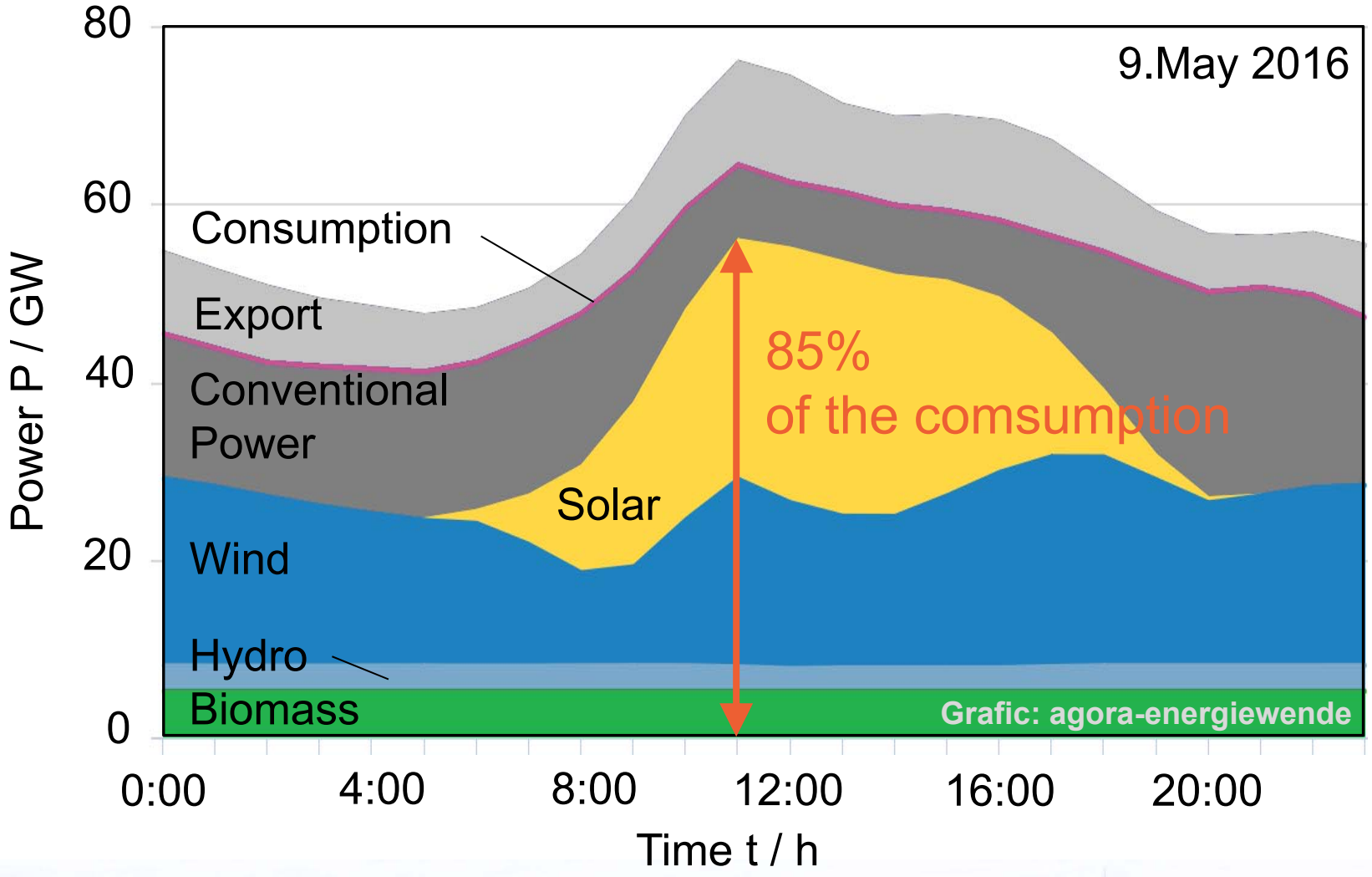
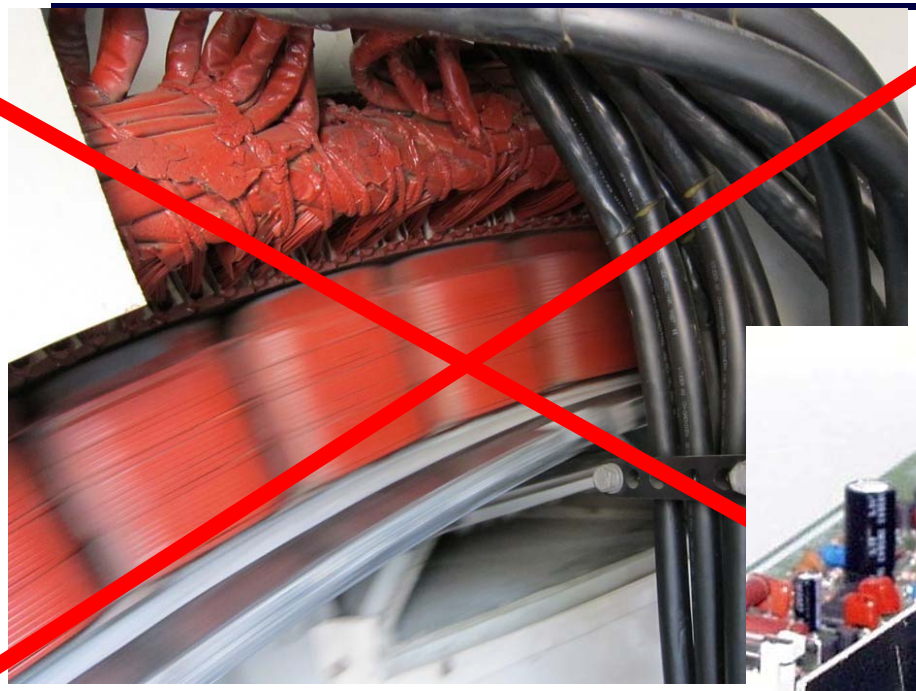
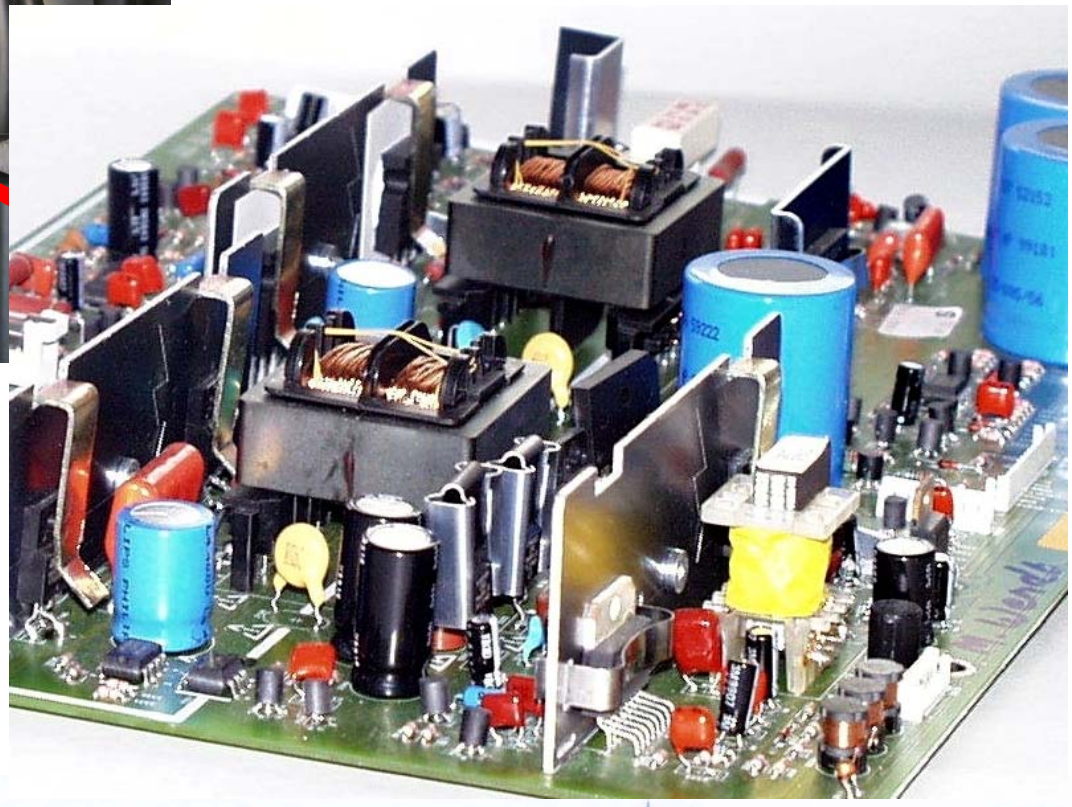
*Acknowledgements to*:
Daniel Wagner, Markus Korbmacher, Bente Muhr, Sonny Glesmann and Nora Kovacs.

# Sometimes 85% RE in the grid

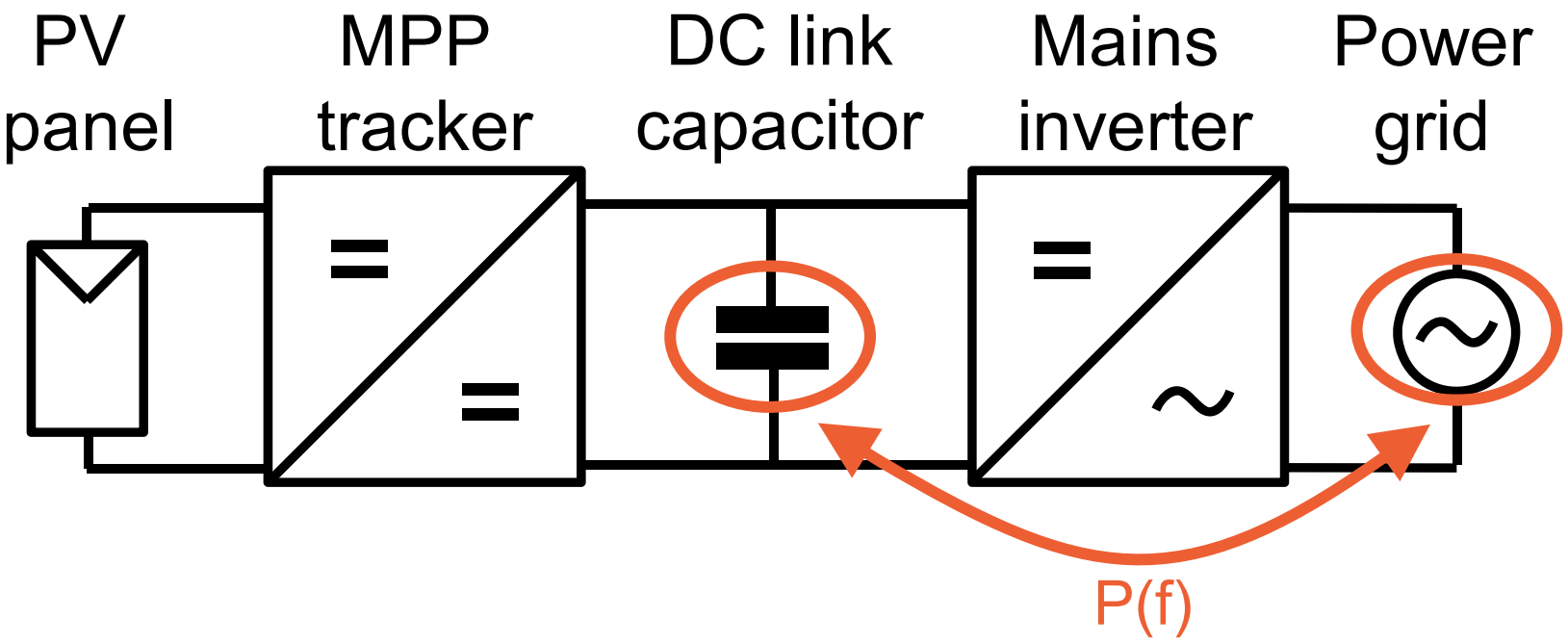


# Conventional generators will be missing

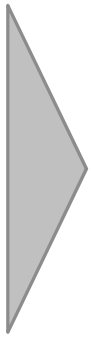




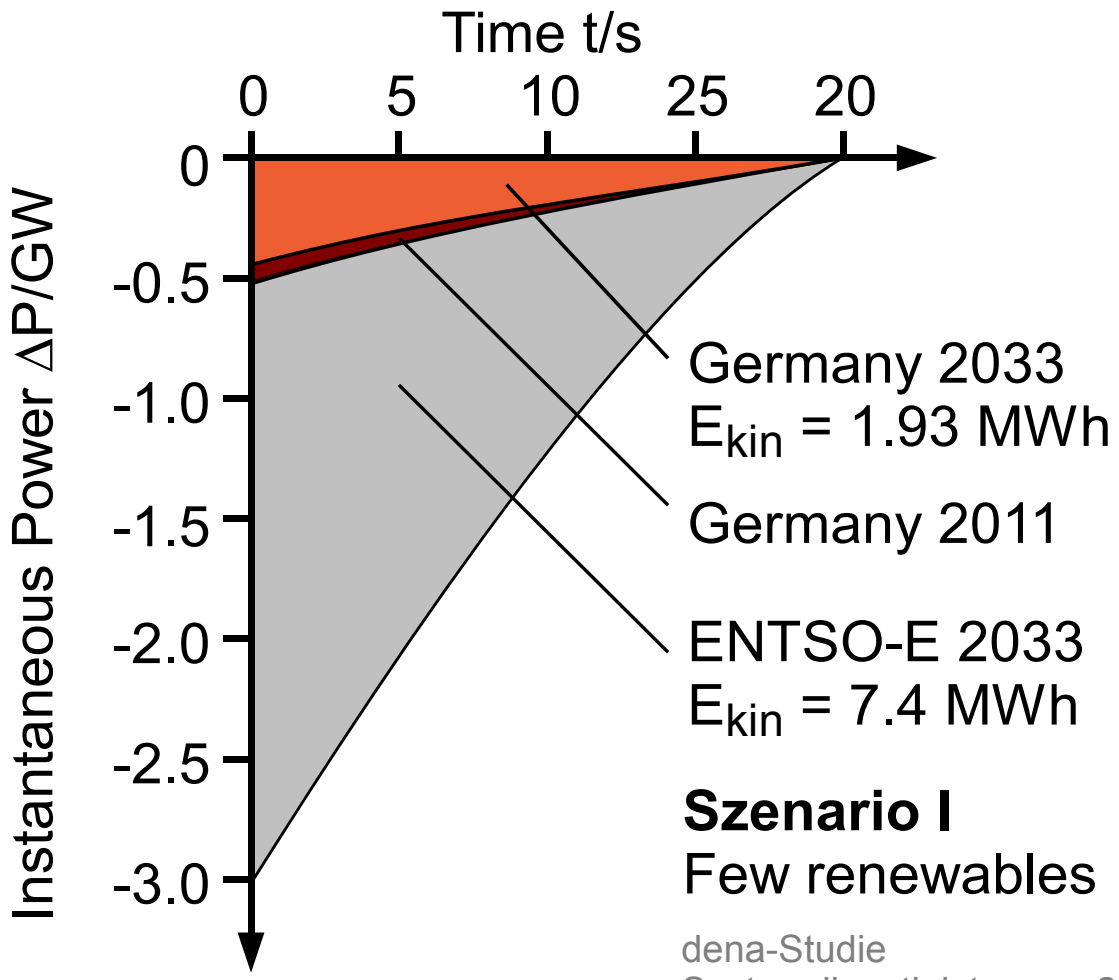
# Topology for virtual inertia



# Worst case and size



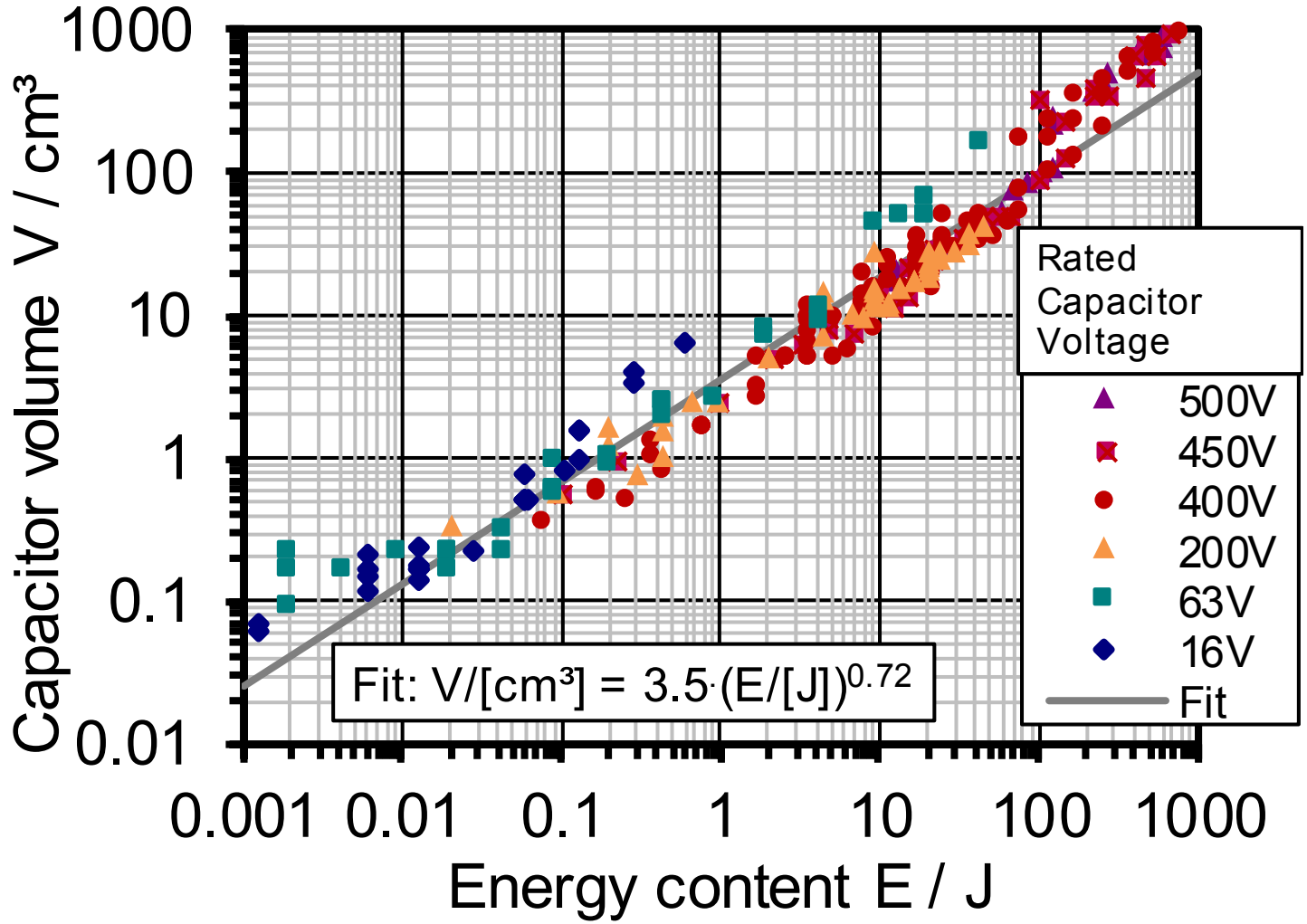
# Required Energy




dena-Studie
Systemdienstleistungen 2030

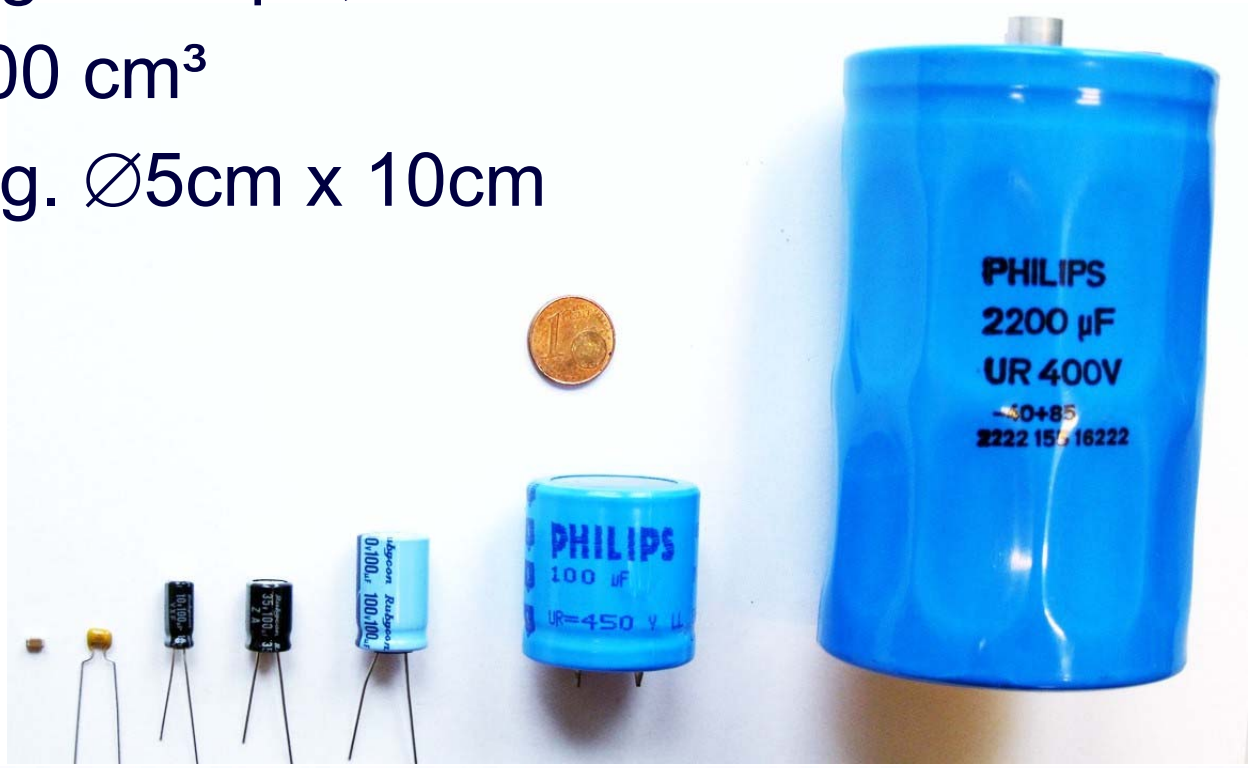
- Contribution of Germany to Instantaneous Control:
  - Energy: 3700 MWs
  - Power: 372 MW
- With feed in of 80 GW:
  - Power: 5W / kW
  - Energy:
  - 50Ws / kW

# Size of electrolytic capacitors

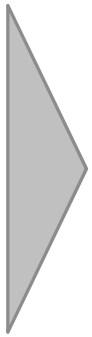


# Needed capacitor size for 1kW

- 50J ⇔ 100% voltage ripple
- 300J ⇔ 10% voltage ripple
- ⇔ e.g. 3500µF, 400V
- ⇔ 200 cm³
- ⇔ e.g. ∅5cm x 10cm



# Daily operation



# 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:

$$E_0 = \frac{1}{2} \cdot C \cdot U_0^2$$

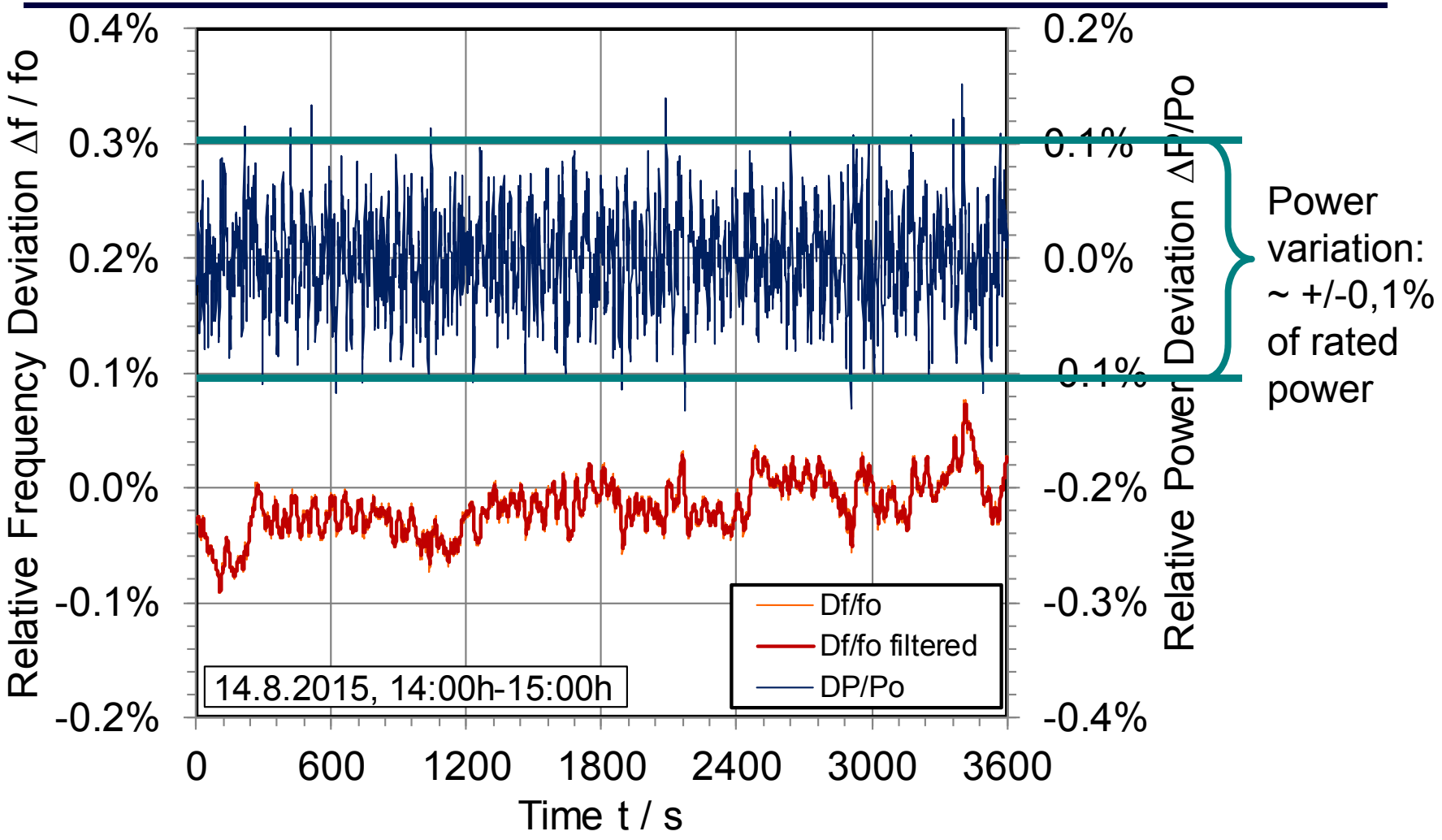
Solution:

$$\frac{\Delta U_c(t)}{U_0} = T_a \cdot \frac{1}{2} \cdot \frac{P_0}{E_0} \cdot \frac{\Delta f}{f} \quad \Rightarrow \quad \frac{\Delta U_c(t)}{U_0} \propto \frac{\Delta f}{f}$$

$\Delta_P$ = Power step
$P_0$ = Power in the grid
$\Delta f$ = Frequency variatrion
$f$ = Grid frequency
$C$ = Capacity of the capacitor
$I$ = Current into the capacitor
$U_0$ = Intermediate voltage
$\Delta U_c$ = Voltage variation at capacitor

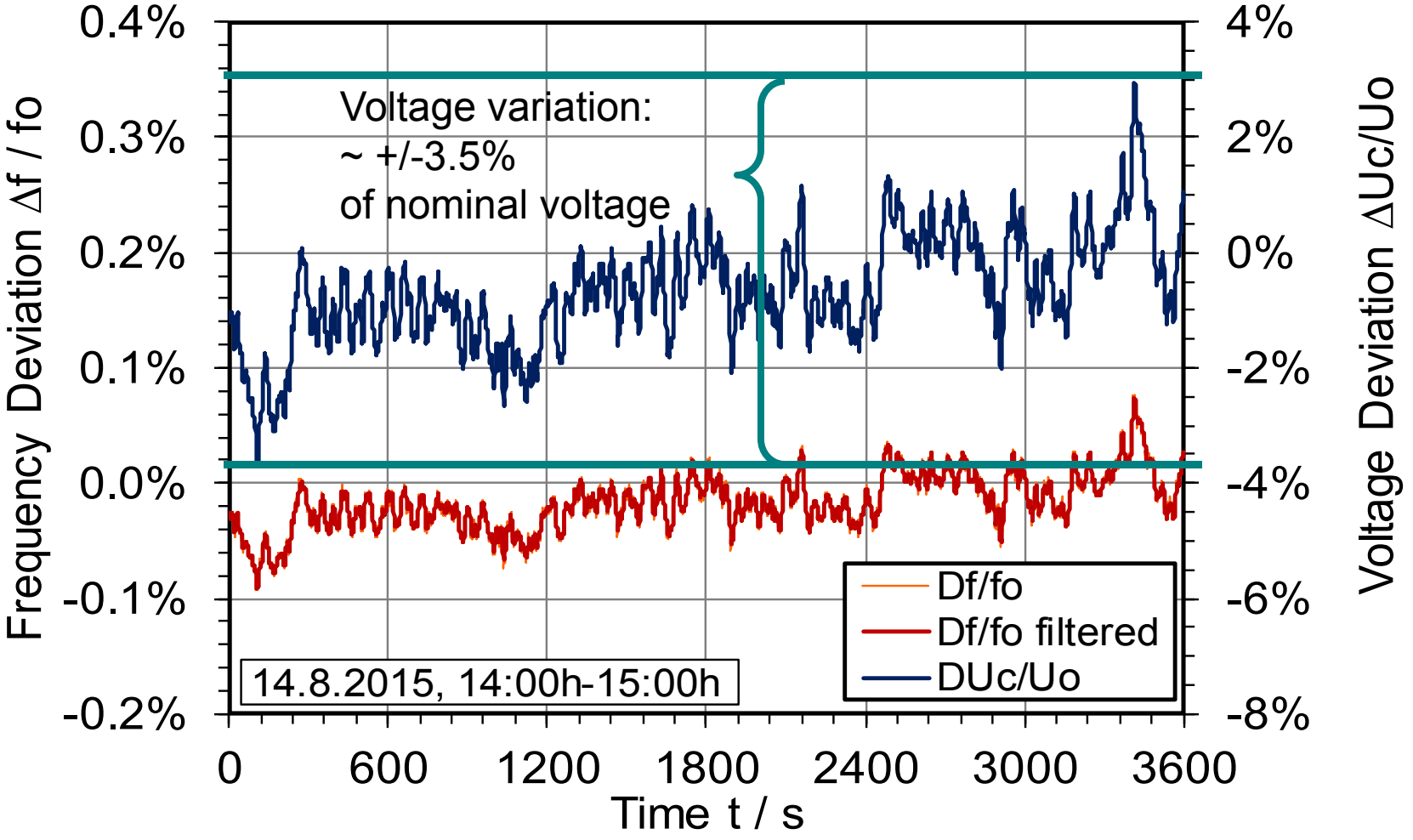
Voltage variation at the capacitor is proportional to the frequency variation

# Power variation



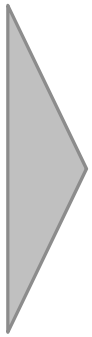

No significant impact on components

# Variation of intermediate voltage




No significant impact on power stage

# Control approach



# Idea of the control

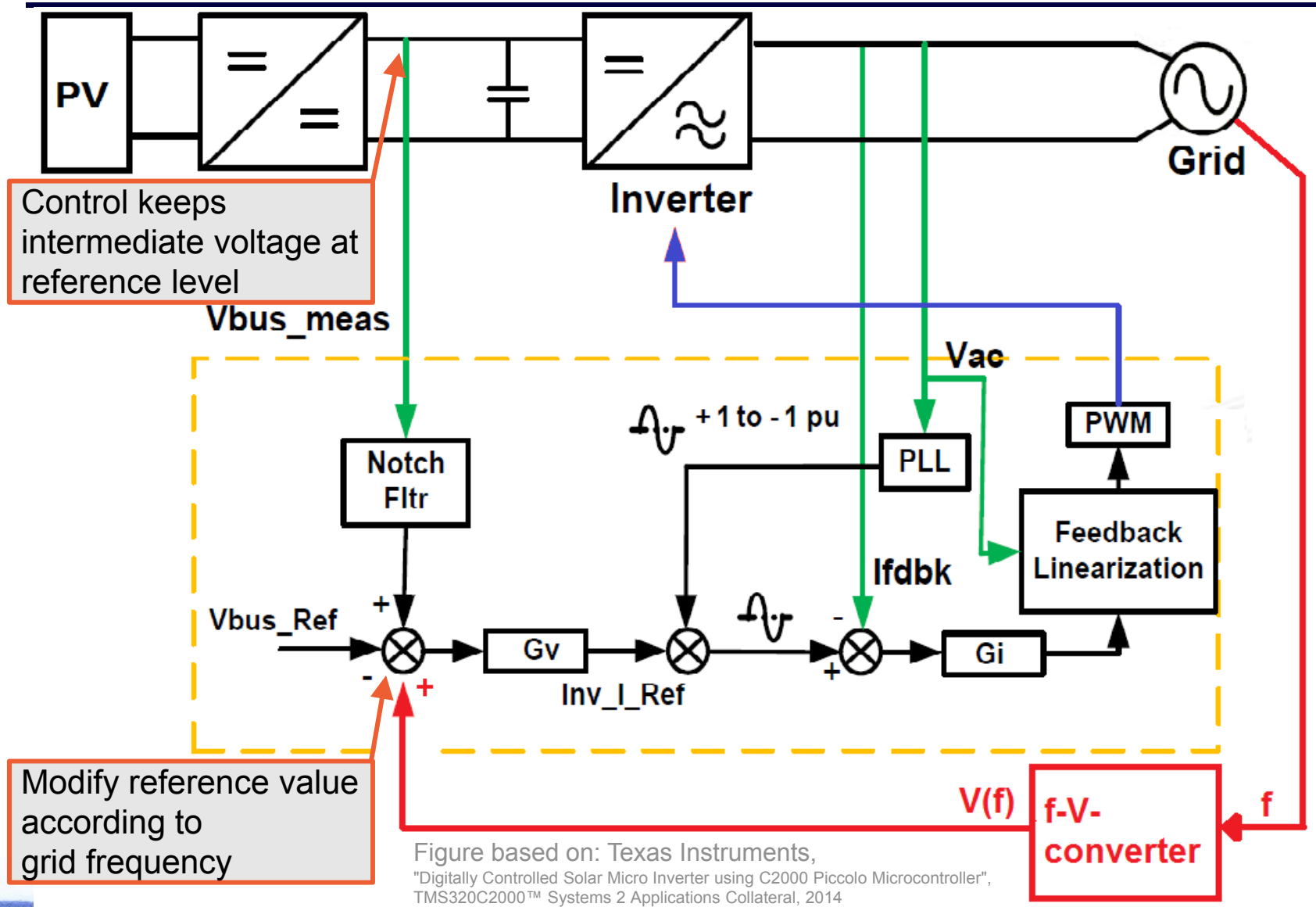



Figure based on: Texas Instruments,
"Digitally Controlled Solar Micro Inverter using C2000 Piccolo Microcontroller",
TMS320C2000™ Systems 2 Applications Collateral, 2014

# Realized test circuit with PFC controller

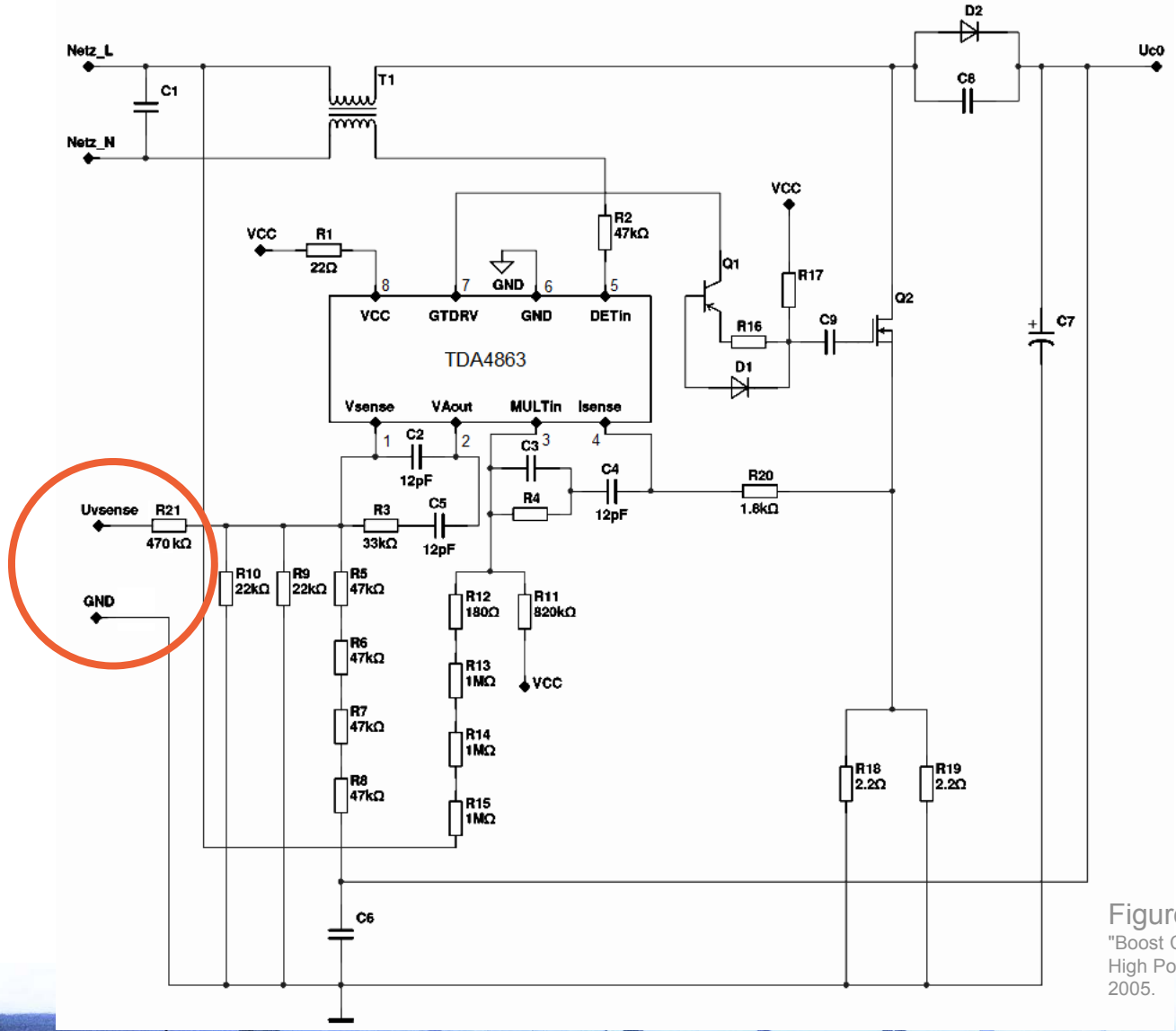
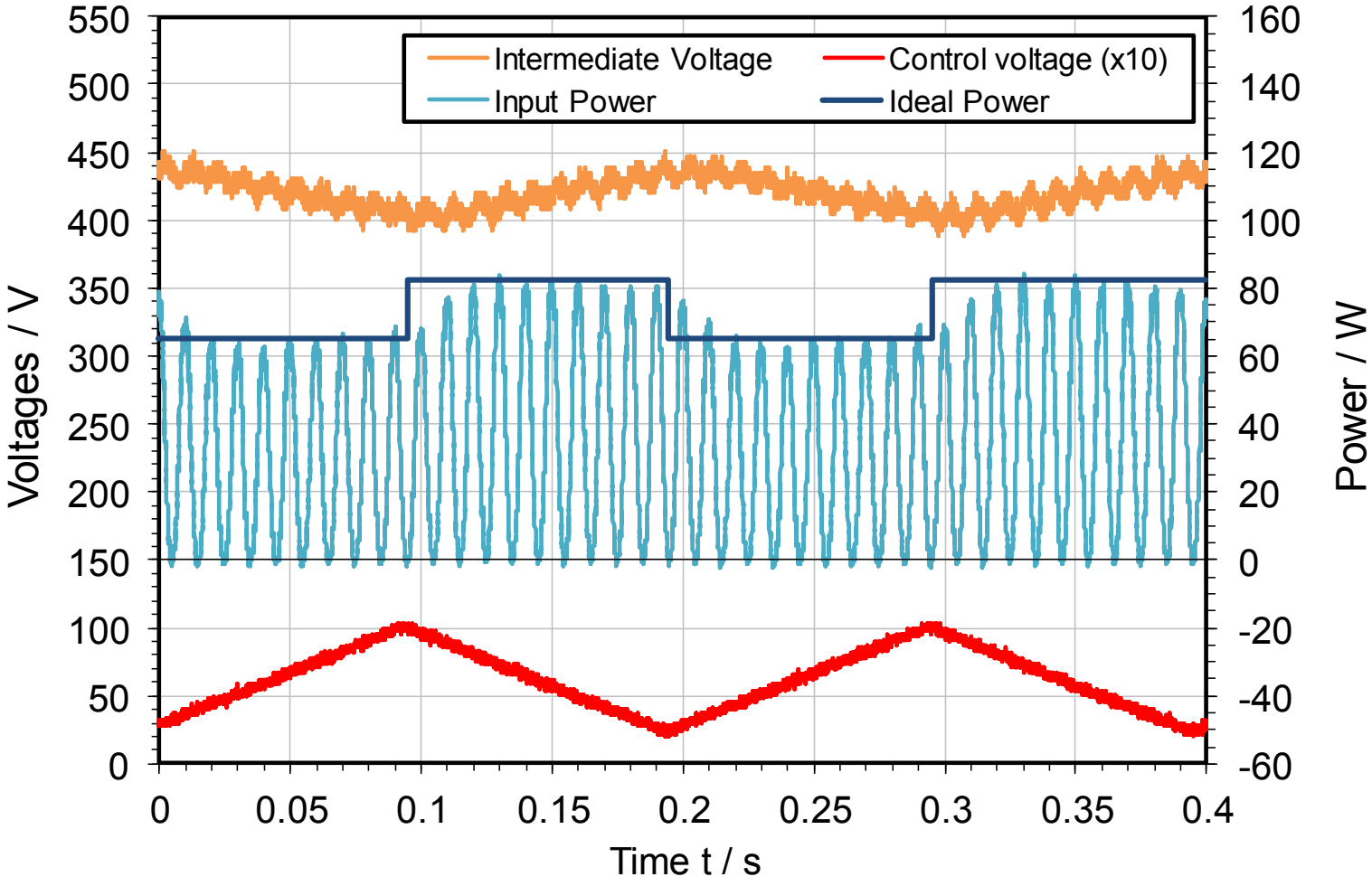
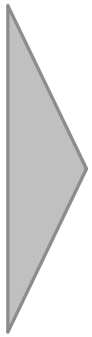



Figure based on: Infineon,
"Boost Controller TDA4863 - Power Factor Controller IC for High Power Factor and Low THD", Datasheet, Rev. 2, Feb. 2005.

# Measurements: Artificial frequency signal



# Conclusion



# Virtual inertia with power inverters

Use intermediate voltage capacitor:

- Existing hardware can be used
- Control easily adapted

# Contact

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