Technology
Arts Sciences
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# Virtual Inertia Grid Control with LED Lamp Driver

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Faculty 07 – Electrical Power Engineering

Examiner: Prof. Dr. Eberhard Waffenschmidt
Co-examiner: Prof. Dr. Christian Dick

# Content

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- Substitution of the rotating inertia
- Development process
- Measurement results
- Conclusion

# Motivation

- Maintaining the balance of the power generation and consumption
- Compensation with additional power (instantaneous reaction) from rotating inertia
- With more renewable energy sources → less conventional generators
- Solution: using the feed-in inverters as "virtual inertia"
  - The need of an electric storage
  - The existing inverters are not easy to be modified

**Idea: virtual inertia control in electronic power supply of loads**

# Motivation

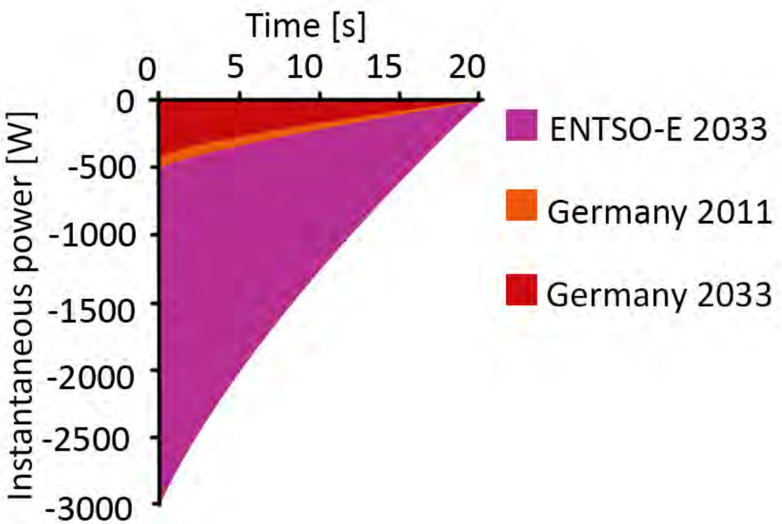
Instantaneous power in the European ENTSO-E grid :

- worst case: 3 GW load step
- 5W power
- 50Ws energy

} per installed kW

Instantaneous power in Germany

- 372 MW power
- 3720 MWs energy




Instantaneous power reserve for the worst case of a sudden load change of 3 GW in European ENTSO-E grid [1]

# Substitution of the rotating inertia

In case of an error:

- If there is not enough rotating inertia in the power network
  - Power deficit → decreasing frequency

$$\frac{\Delta P(t)}{P_0} = T_A \cdot \frac{d}{d(t)} \cdot \frac{\Delta f(t)}{f_0}$$

Where

$\Delta P$ : power which is needed by the load
$P_0$ : nominal power of the power network
$T_A$ : time constant (20s)
$\Delta f$ : deviation from the nominal frequency
$f_0$ : nominal frequency

# Substitution of the rotating inertia

$$\frac{\Delta U_C(t)}{U_0} = T_A \cdot \frac{1}{2} \cdot \frac{P_0}{E_0} \cdot \frac{\Delta f}{f_0}$$ [2]

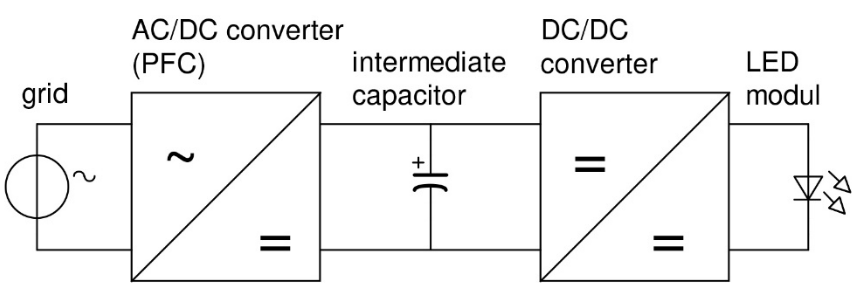
Where

$\Delta U_C/U_0$ : voltage fluctuation in the capacitor

$\Delta f/f_0$ : frequency fluctuation

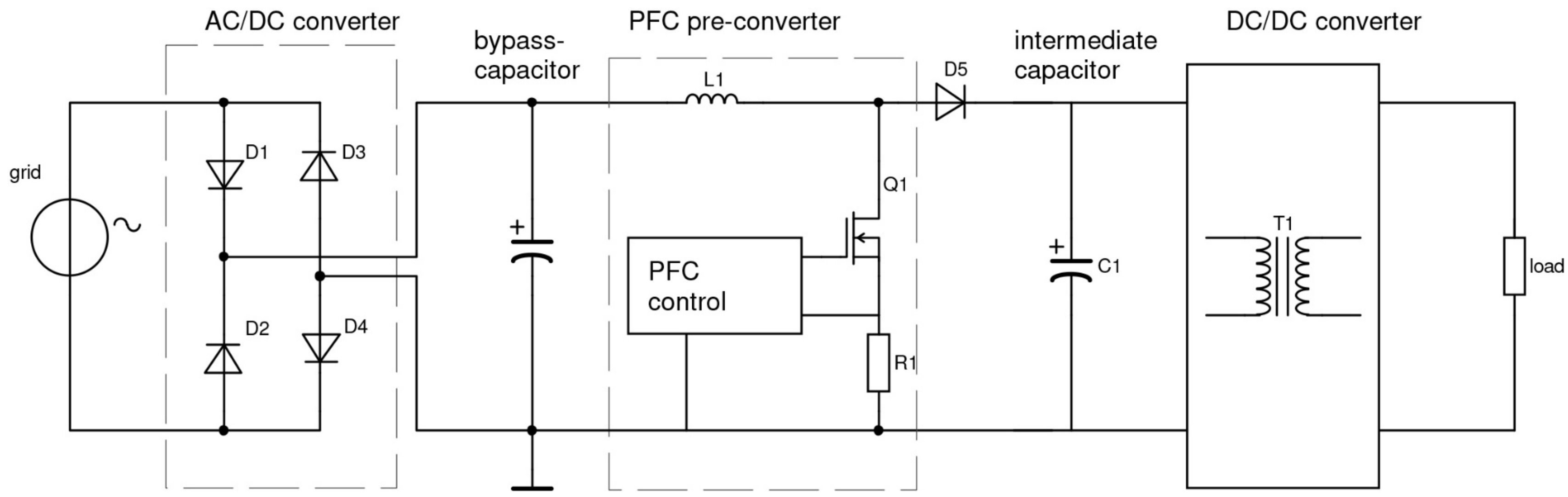
## Approach

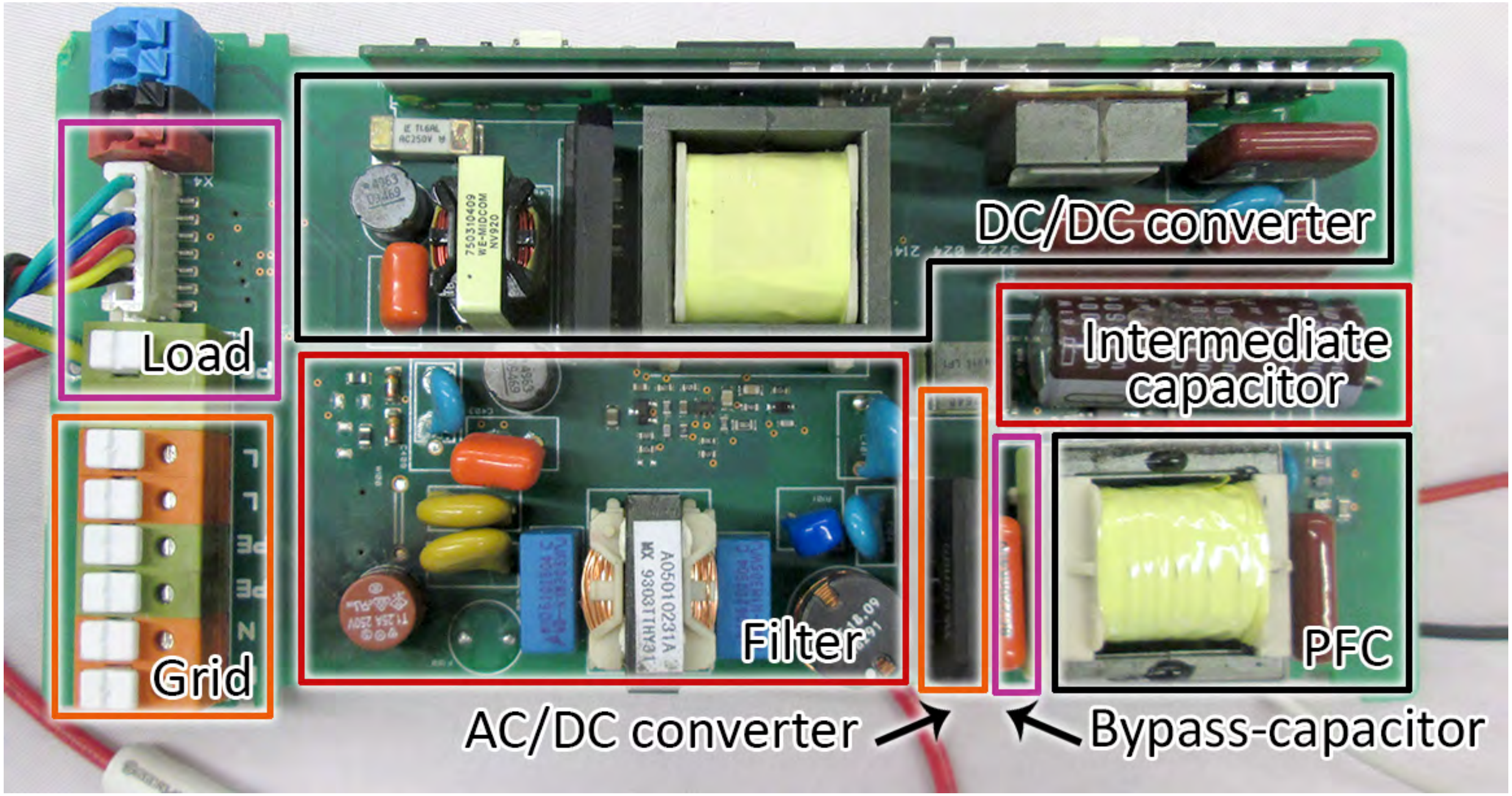
- intermediate capacitor
- in LED Lamp Drivers




# Development process – Control method

- Controlling the PFC (Power Factor Correction) circuit in the LED driver
  - Responsible of the charge of the intermediate capacitor
  - Controls the value of the real power of the driver [3]



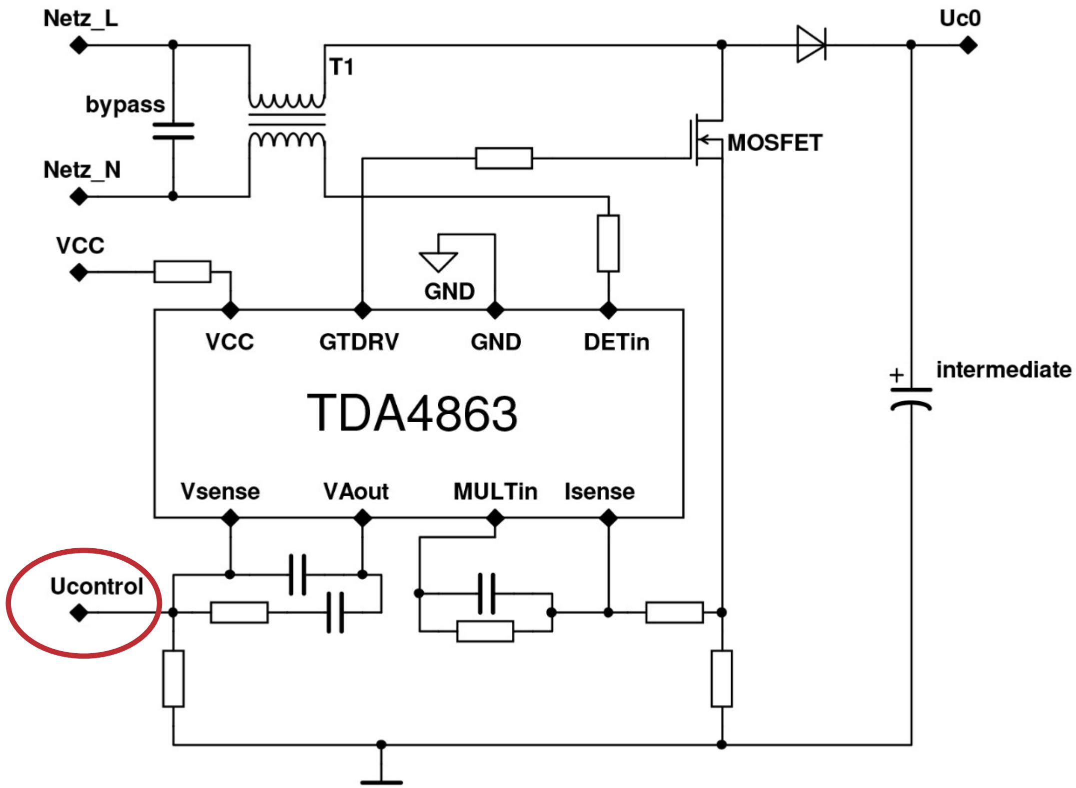

Load
DC/DC converter
Intermediate capacitor
Grid
Filter
PFC
AC/DC converter
Bypass-capacitor

# Development process - PFC

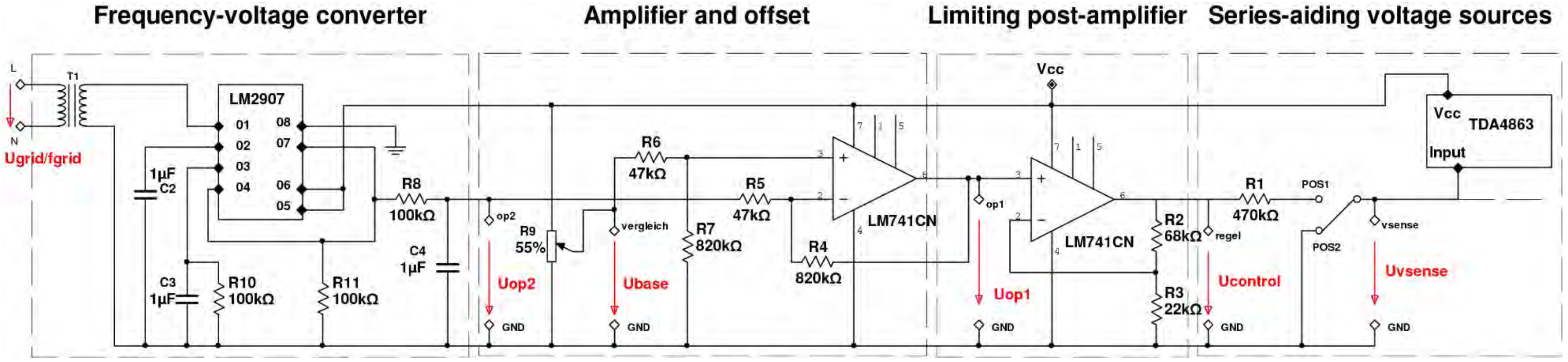
- Controlling the PFC
  - TDA4863
  - VSENSE input

- fgrid > 50Hz →
  - Ucontrol decreasing
  - Uc0 increasing
- fgrid < 50Hz →
  - Ucontrol increasing
  - Uc0 decreasing

Without control: Ucontrol = 2.5V
Maximum: Ucontrol = Uvcc = +15V
Minimum: Ucontrol = GND = +0V

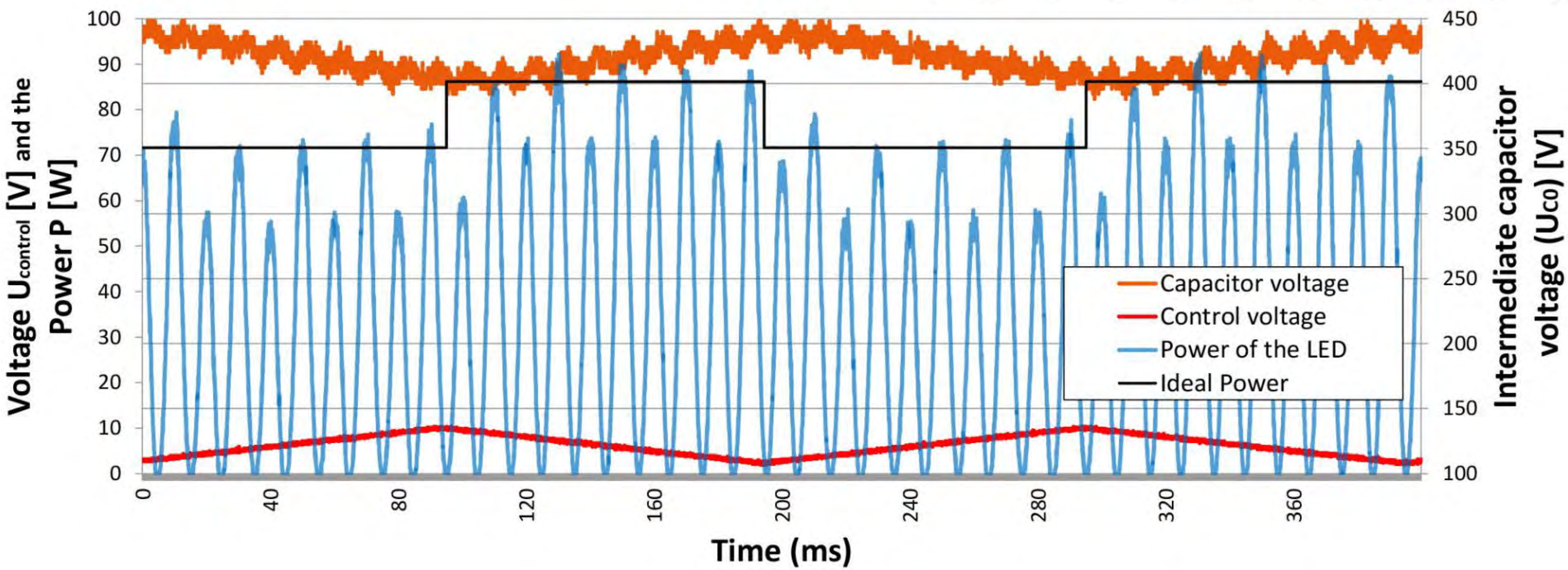


# Development process – Control circuit



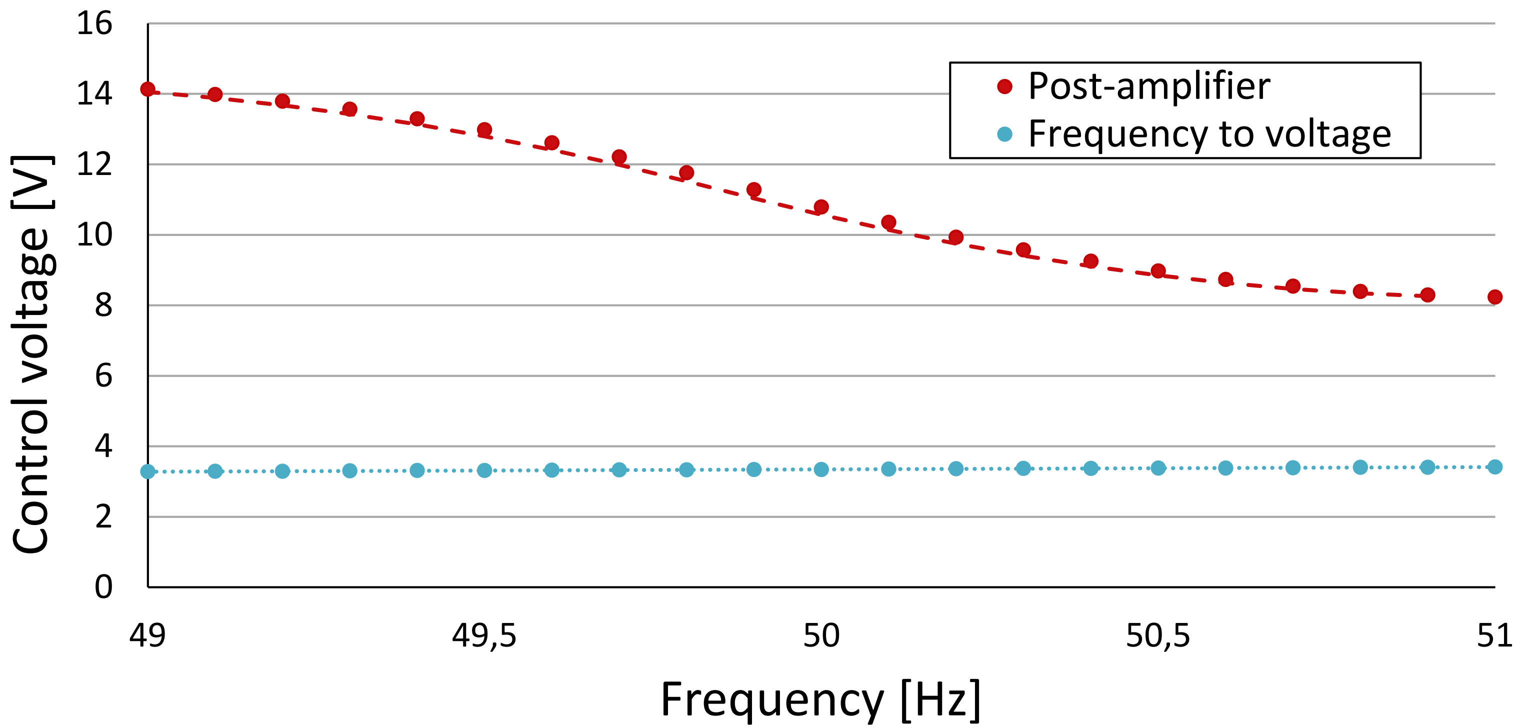
# Development process – Triangular control signal

- The *Control voltage* is a signal based on the simulated grid frequency:
  - 6V offset
  - 4V amplitude
  - 1 Hz

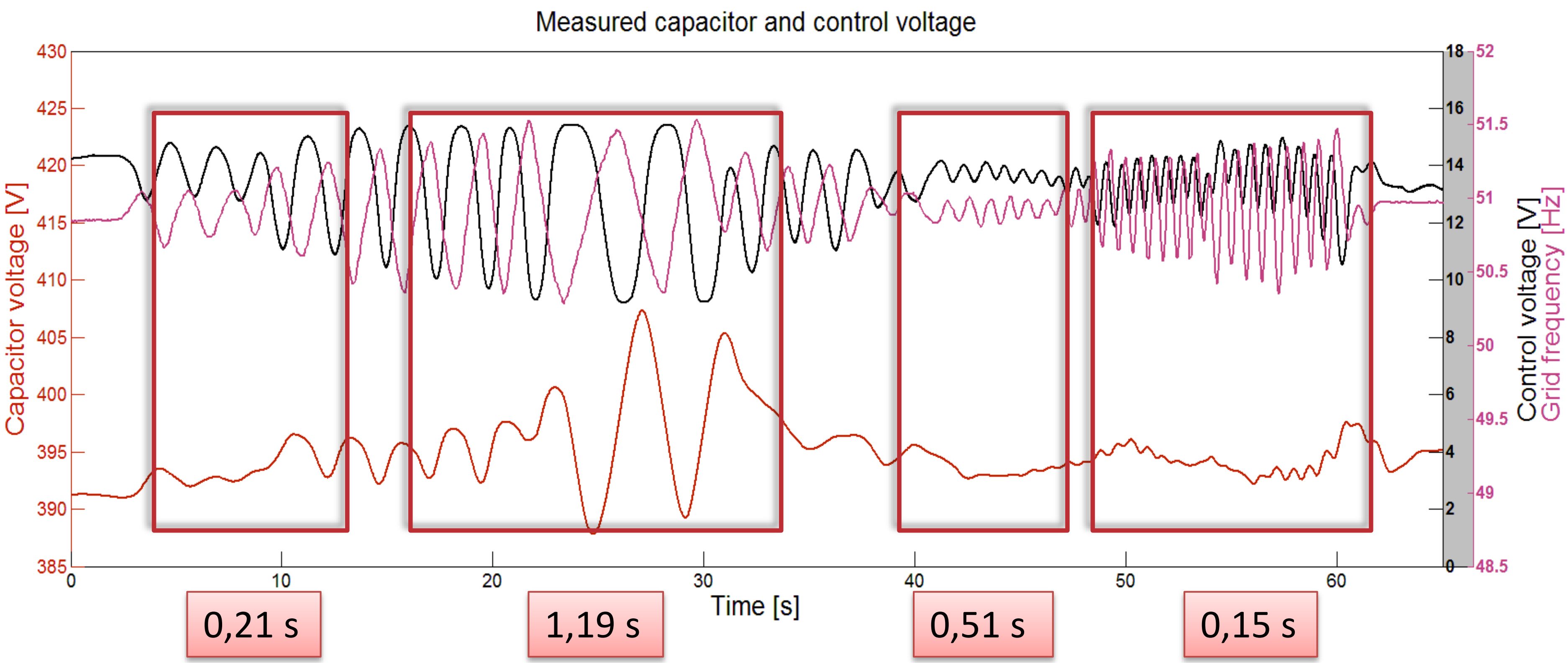


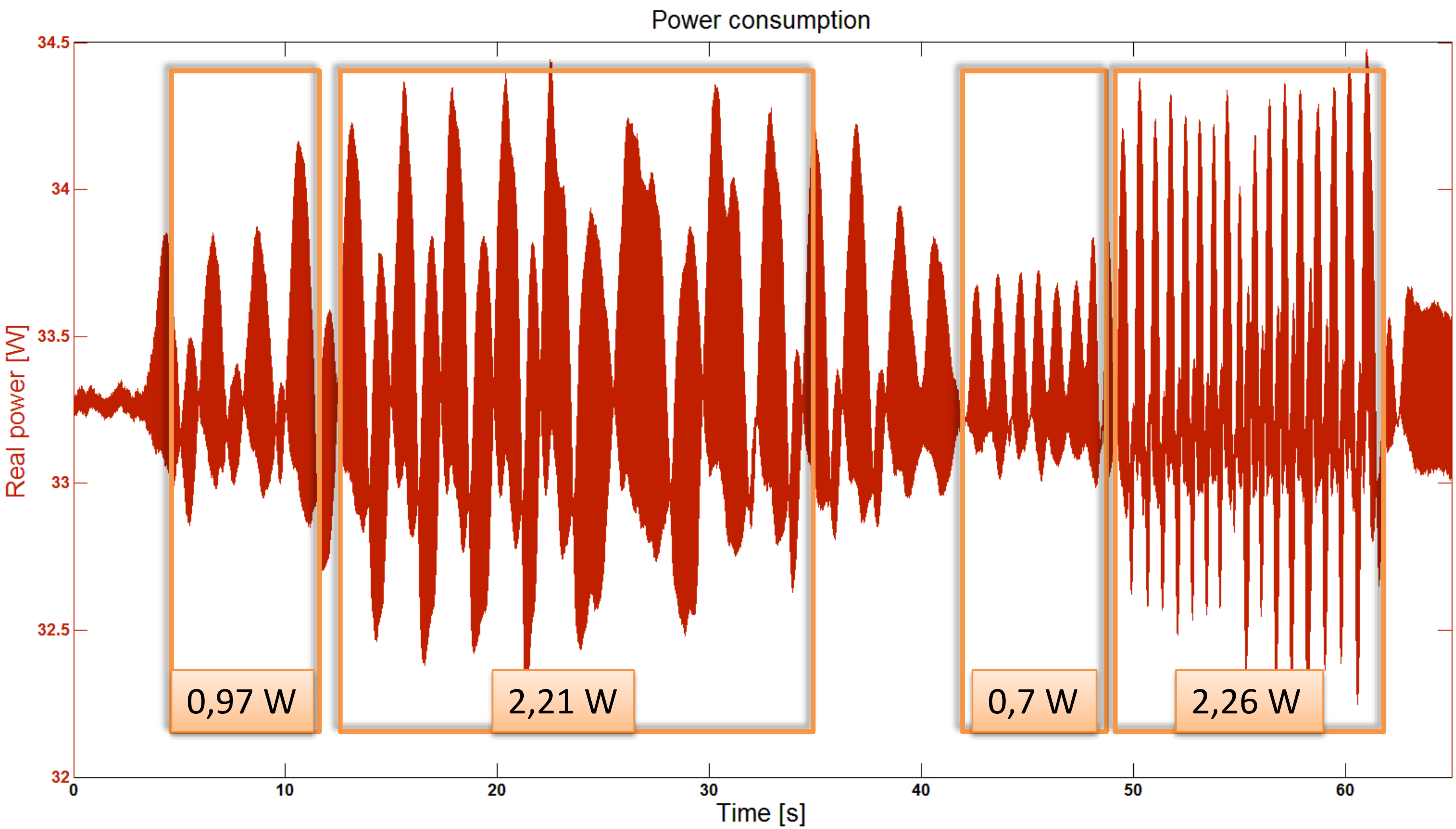
# Development process – Synchronous generator

- With a help of an frequency to voltage converter (LM2907)

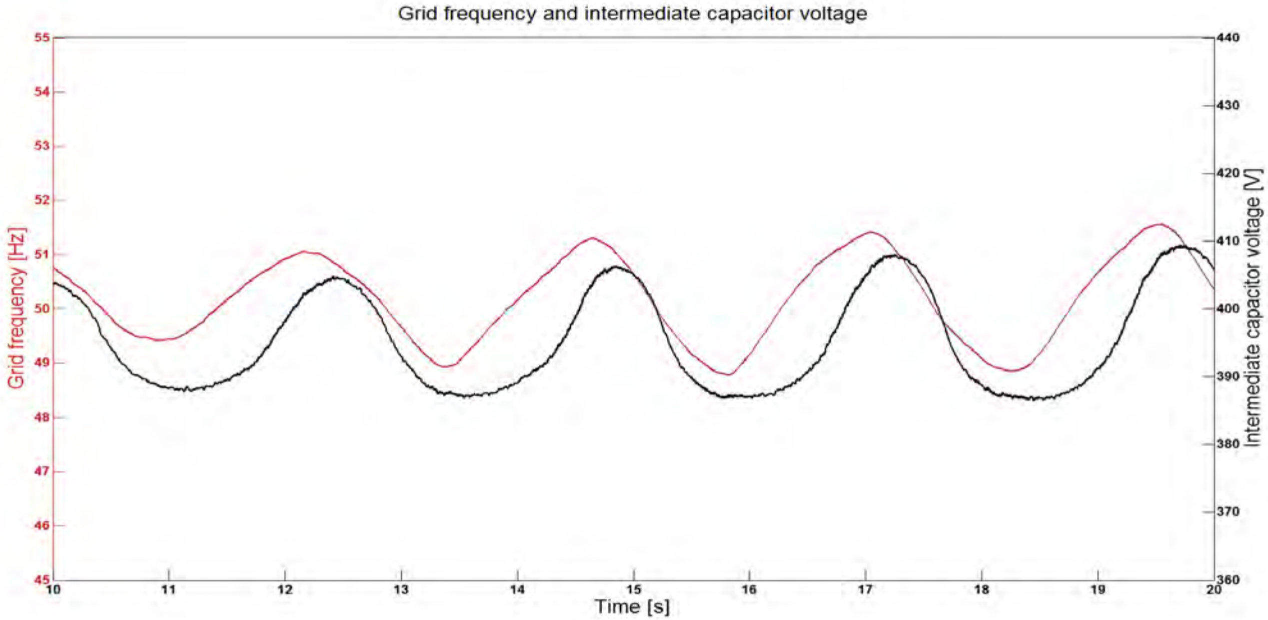


# Measurement results



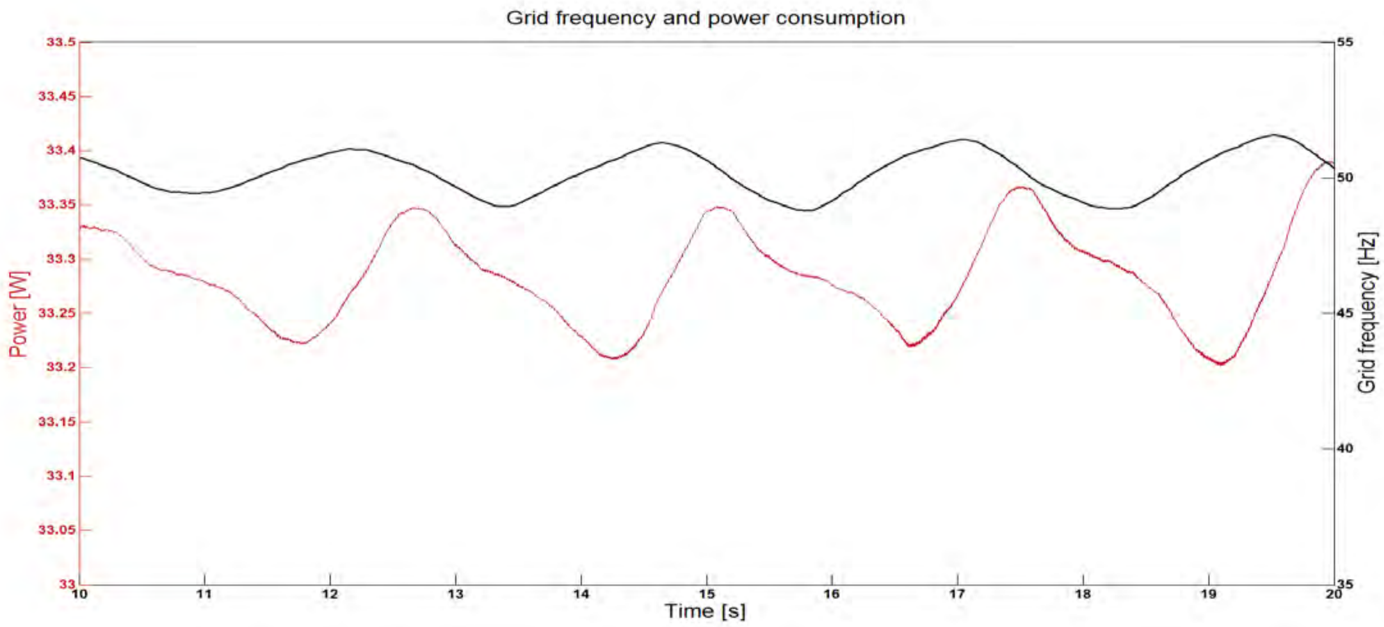

Power consumption
Real power [W]
34.5
34
33.5
33
32.5
32
0
10
20
30
40
50
60
Time [s]
0,97 W
2,21 W
0,7 W
2,26 W

# Measurement results




| Control speed | Power fluctuation | Frequency |
|---|---|---|
| 0,21 s | 0,97 W | Small gradient, small amplitude |
| 1,19 s | 2,21 W | Small gradient, big amplitude |
| 0,51 s | 0,7 W | Big gradient, small amplitude |
| 0,15 s | 2,26 W | Big gradient, big amplitude |

# Measurement results

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# Conclusion

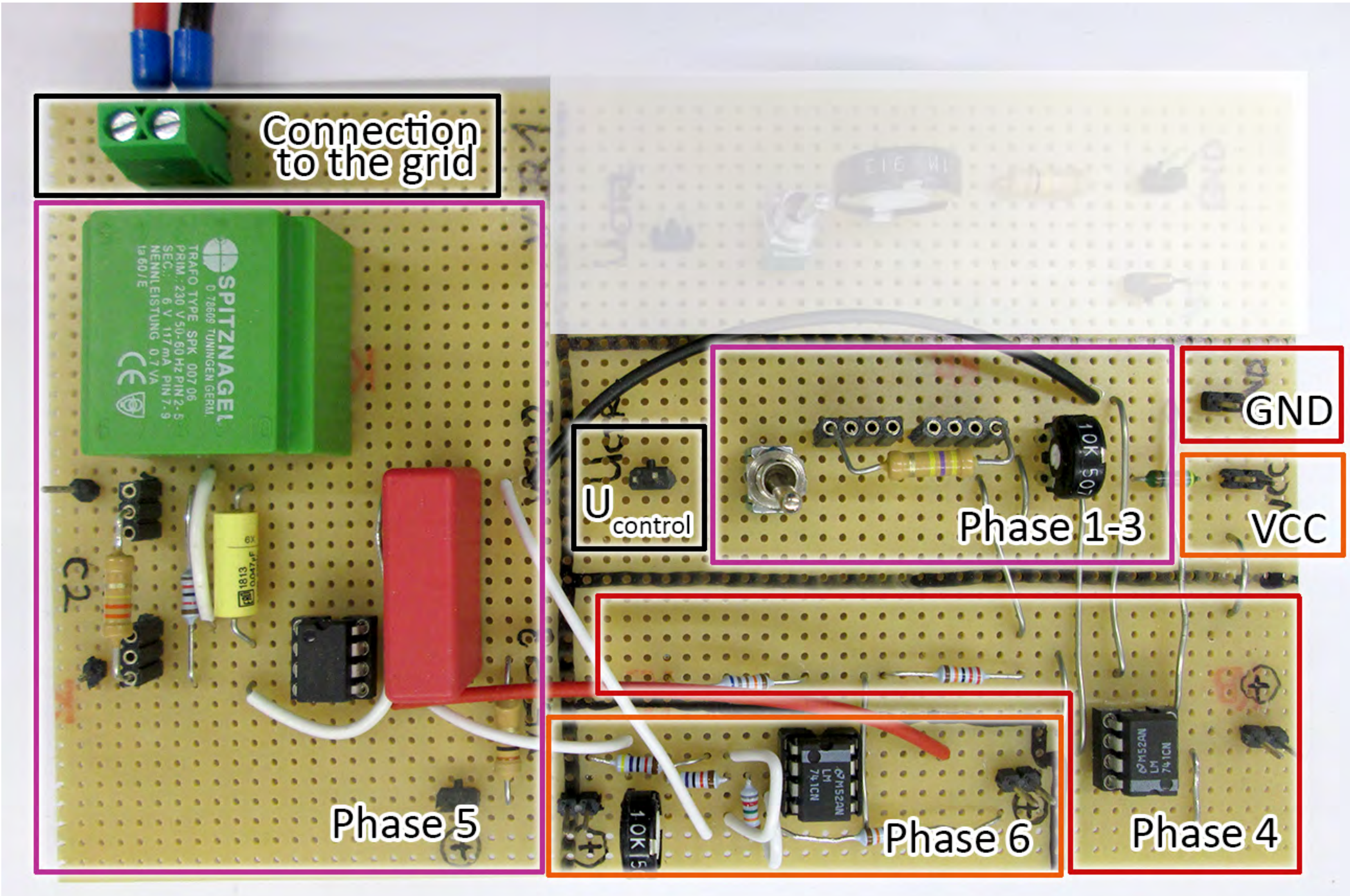
- The designed circuit was able to change the power consumption of the LED lamp driver up to 2.2 W.
- Although this value may be less in case of a daily operation without power failures in an electricity network.
- With this development:
    - The frequency stability of the grid can be maintained
    - No additional hardware is required (cost effective)
    - With the modification of the existing feed-in inverters (easily implemented solution)

# References

[1] A.-C. Agricola,et al., dena-Studie Systemdienstleistungen 2030 – Sicherheit und Zuverlässigkeit einer Stromversorgung mit hohem Anteil erneuerbarer Energien,
DENA, Energiesysteme und Energiedienstleistungen, Berlin, 2014.

[2] E. Waffenschmidt, Momentan-Regelung mit Photovoltaik-Wechselrichtern,
Otti-Konferenz "Zukünftige Stromnetze für erneuerbare Energien", Berlin, 2016.

[3] ON Semiconductor, Power Factor Correction (PFC) Handbook,
http://www.onsemi.com/pub-link/Collateral/HBD853-D.PDF,
angerufen: 21.05.2016, 14:34


Connection to the grid
Phase 5
U control
Phase 1-3
GND
VCC
Phase 6
Phase 4