DC Grid Droop Control for Charging Electric Boats

Fedor Boendermaker, Diëgo Zuidervliet, Peter van Duijsen.

The Hague University of Applied Science, Delft, The Netherlands

5 juli 2023

Introduction

- Harbor eBoat charging
- AC situation
- DC situation
- DC Grid Droop Control
- DC Grid developed Hardware
- Conclusion

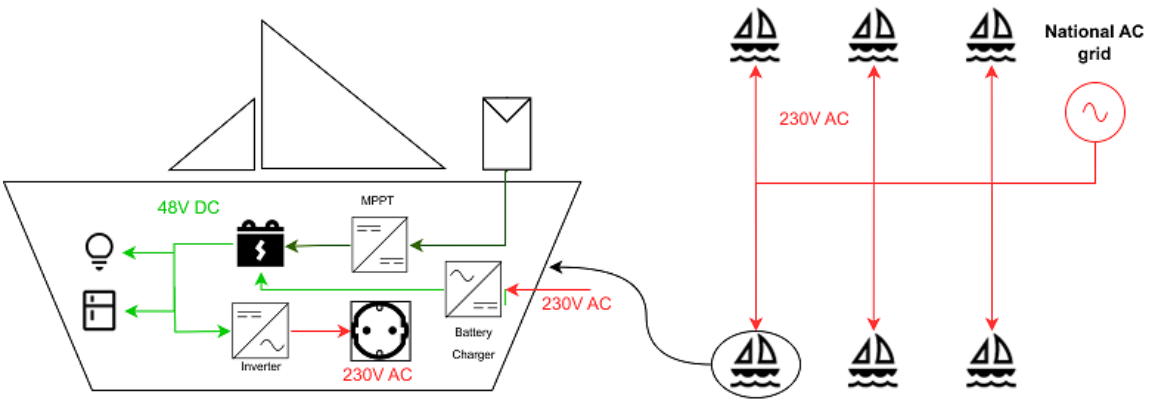
Harbor Marina De Vlietstreek.

Challenges

- Large voltage drop across the grid (100 boats, $\geq$ 350 meter)
- Limited capacity of users at the same time
- Excess solar energy is wasted

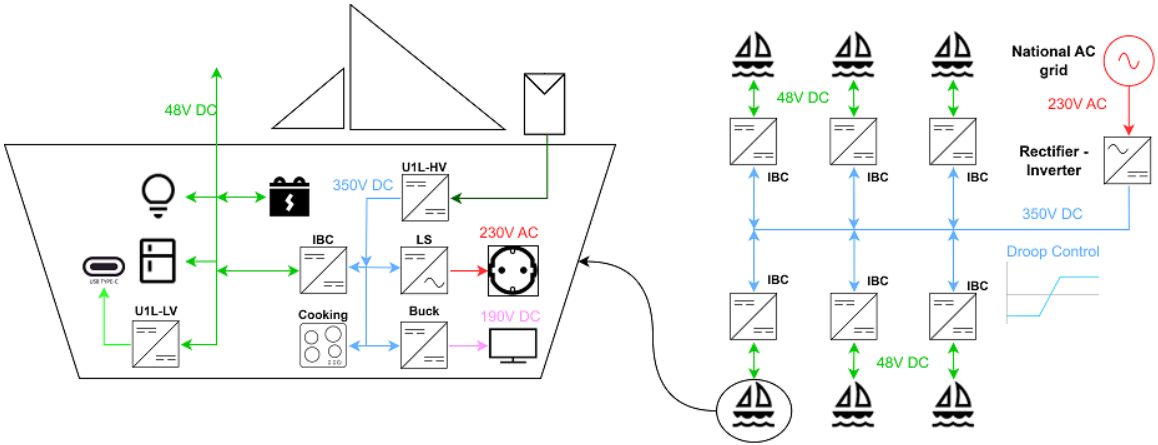
Marina De Vlietstreek.

Existing AC grid



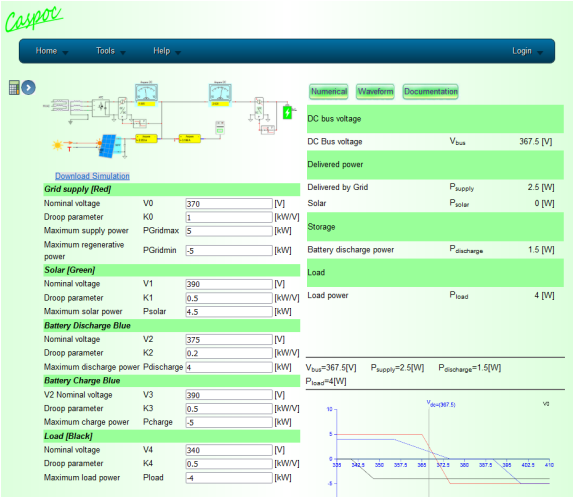
Losses and voltage drop over the cable.

Proposed DC Grid



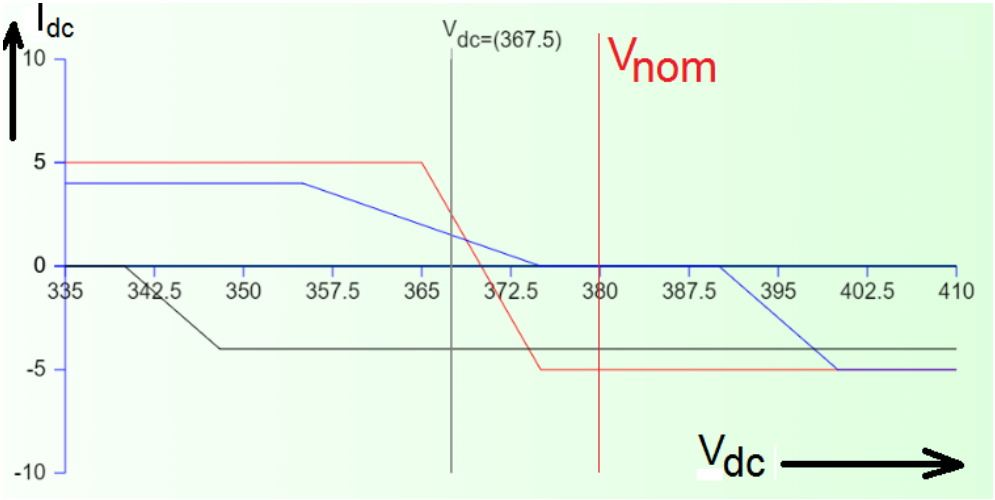
No voltage drop due to impedance, only due to resistance

Droop Control Tool



Design of the droop control characterisitics

Droop Control Tool

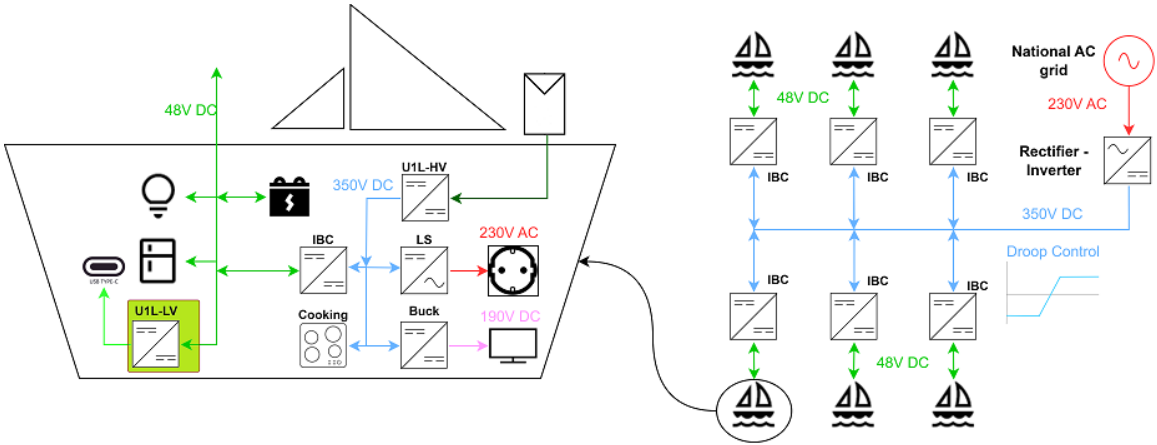


Droop control characterisitics

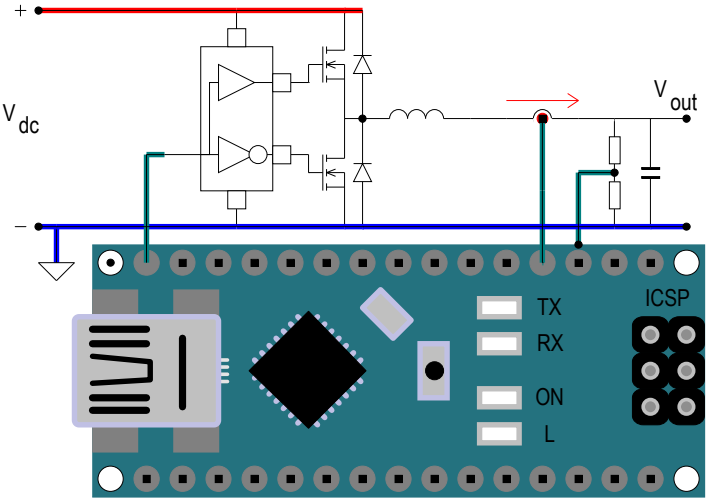
Developed Hardware

- U1L-LV: Universal One Leg
  (Bidirectional DCDC $48\,Vdc \Leftrightarrow 20\,Vdc \cdots 24\,Vdc$)
- U1L-HV: Universal One Leg
  (Bidirectional DCDC $350\,Vdc \Leftrightarrow 350\,Vdc$)
- IBC: Interleaved Boost Converter
  (Bidirectional DCDC $48\,Vdc \Leftrightarrow 350\,Vdc$)
- Buck: Step-down Converter
  (Unidirectional DCDC $350\,Vdc \Rightarrow 192\,Vdc \cdots 230\,Vdc$)
- LS: Legacy Socket
  (Unidirectional DCAC $350\,Vdc \Rightarrow 230\,Vac$)

Universal-One-Leg Low Voltage



Universal-One-Leg Low Voltage



Low Voltage Step down Converter

Control

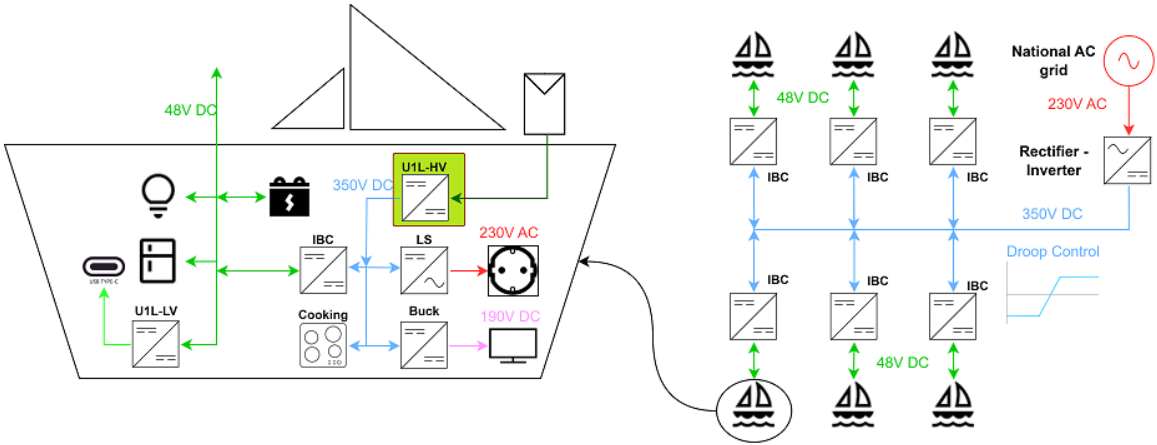
Typical analog Type-II controller for Step-Down converter

$$G_c(s) = G\frac{1 + sR_{comp}C_{comp}}{s(1 + sR_{comp}C_o)} \tag{1}$$

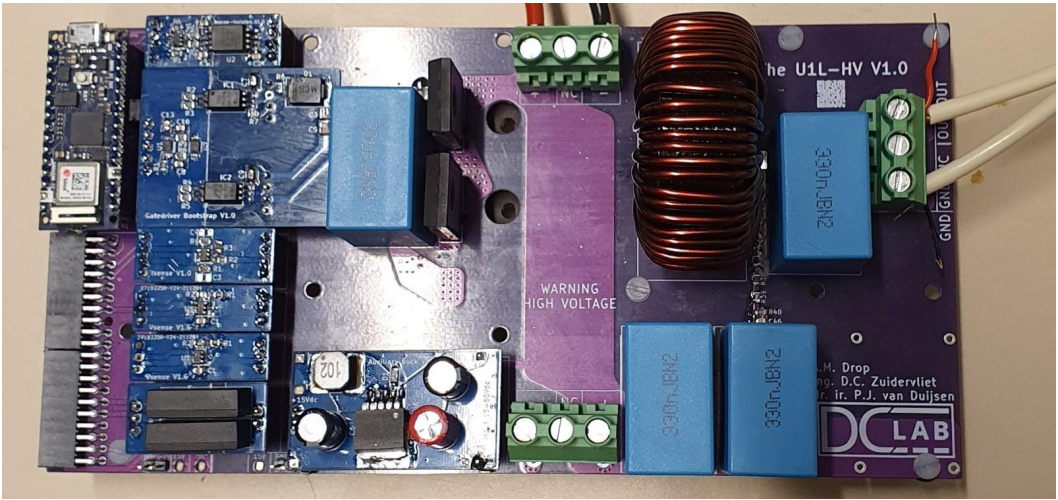
Bilinear Transform

$$s = \frac{2}{T}\frac{z-1}{z+1} \tag{2}$$

Universal-One-Leg High Voltage

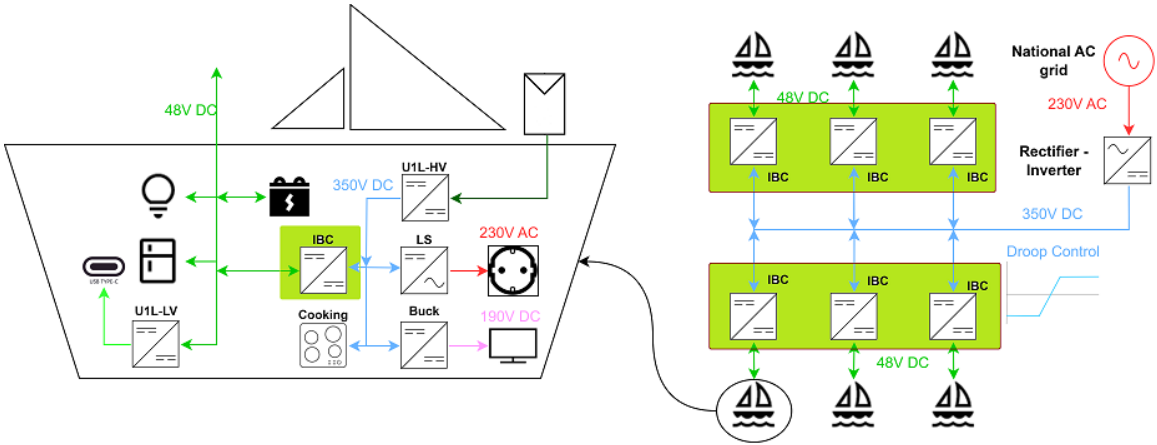


Universal-One-Leg High Voltage

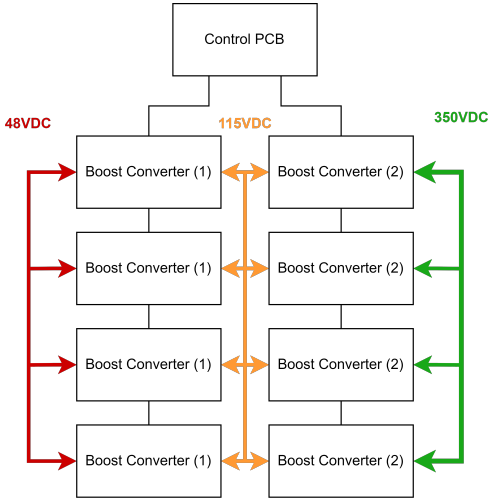


High Voltage Step-Up Converter(Solar Panels)

Interleaved Boost Converter

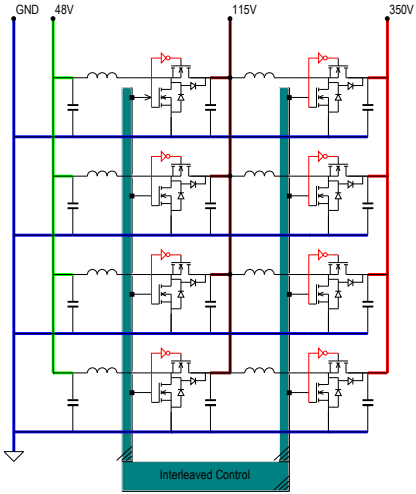


Interleaved Boost Converter



Bidirectional Buck / Boost converter, Interleaved

Interleaved Boost Converter

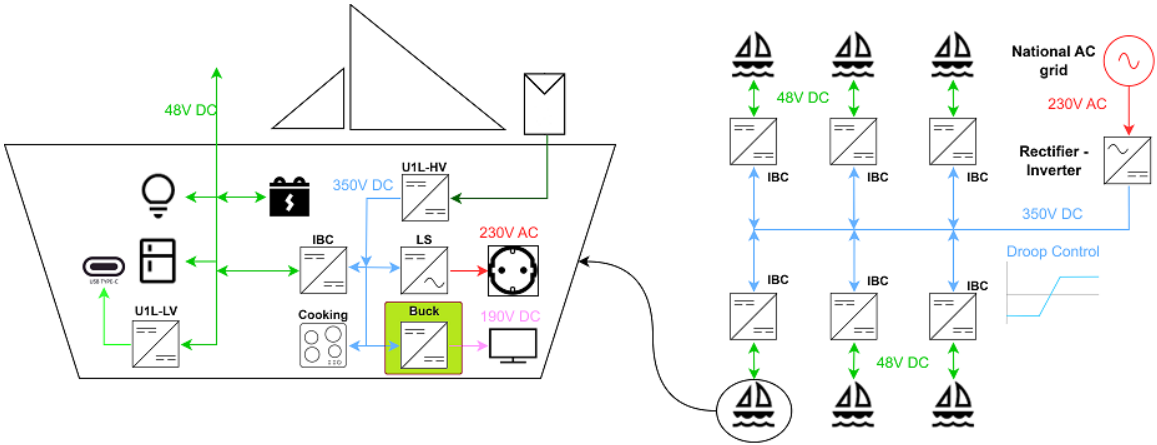


Interleaved bidirectional boost converter Schematic

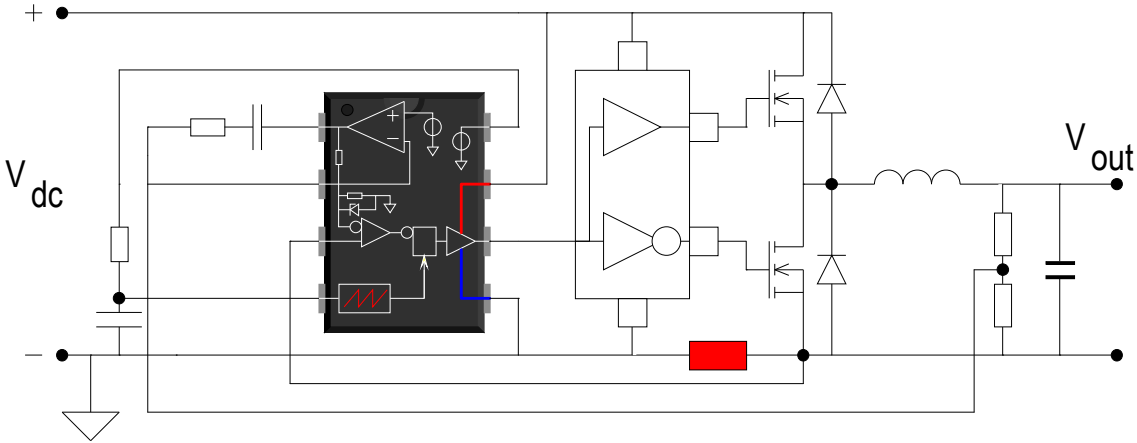
Interleaved Boost Converter

Interleaved bidirectional boost converter PCB

Buck converter

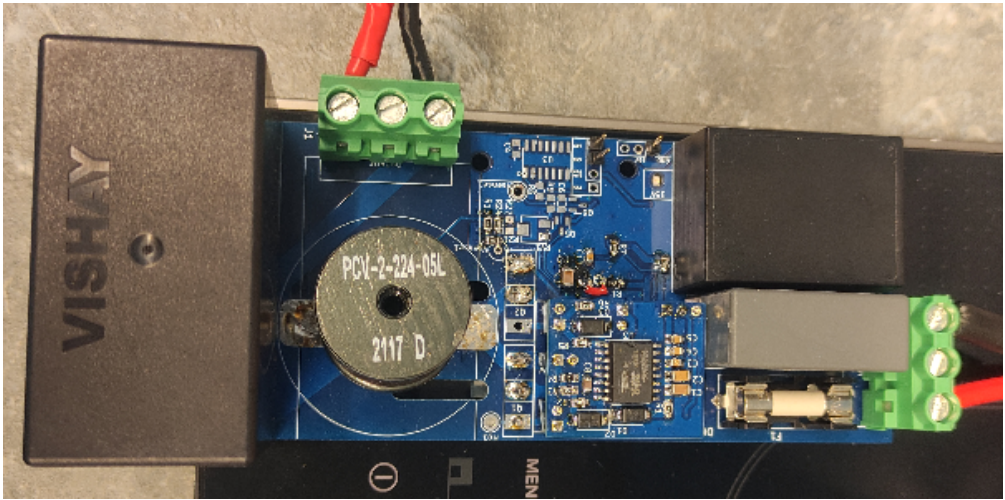


Buck converter



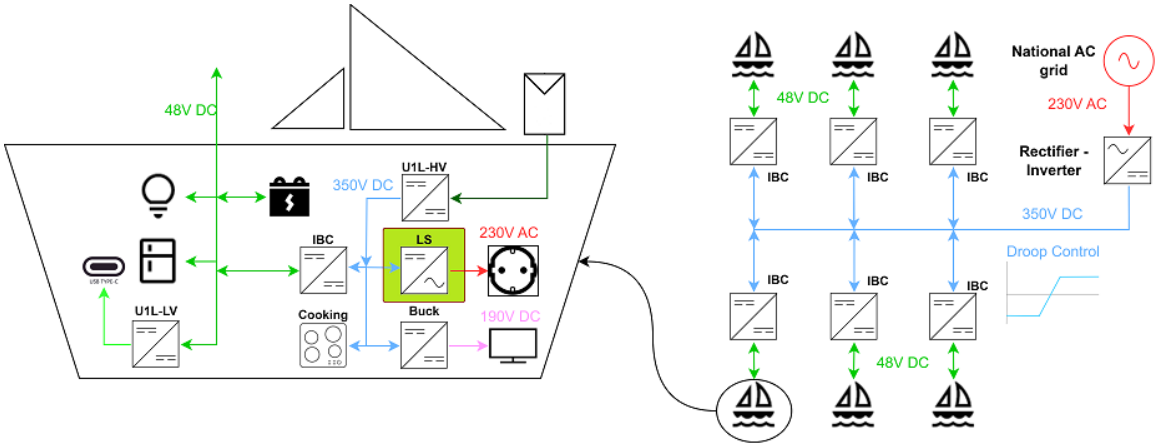
Buck converter with current mode control and floating output.

Buck converter

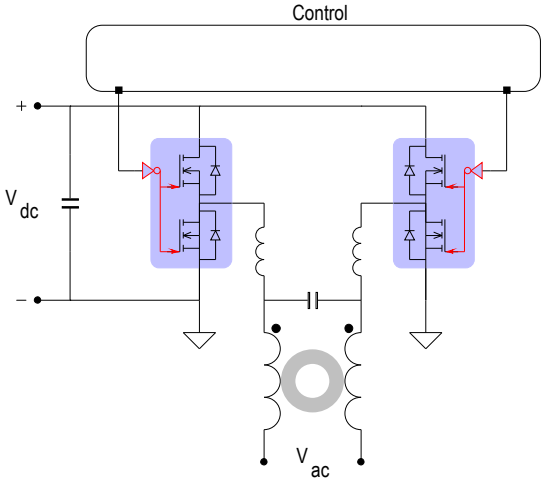


Step down converter design

Legacy Socket

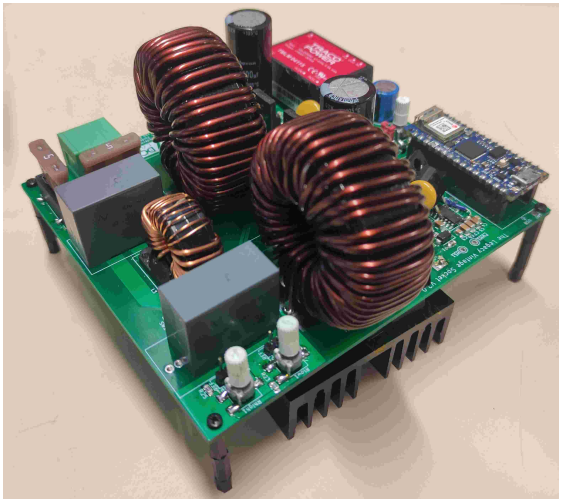


Legacy Socket



Schematic, Legacy socket, to create AC230V/50Hz from DC350V.

Legacy Socket



Design, Legacy socket, to create AC230V/50Hz from DC350V.

Conclusion

- Challenges in the AC Grid
  - Unacceptable large voltage drop along the AC grid.
  - Power Congestion
- Droop Control in DC grid:
  - Equally share solar power
  - Power consumption controlled by DC voltage level
- Developed hardware (4 Converters)
  - DCDC and DCAC converters

www.dc-lab.org 

www.caspoc.com