DC grids for marine charging and electric propulsion
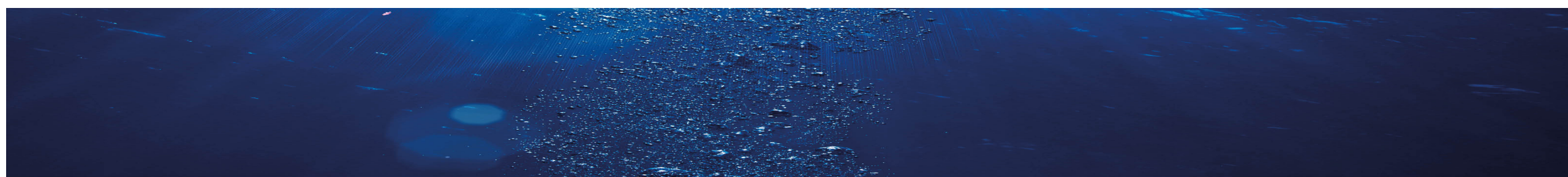
Prof.oP. dr. ir. P.J. van Duijsen

The Hague University of Applied Sciences

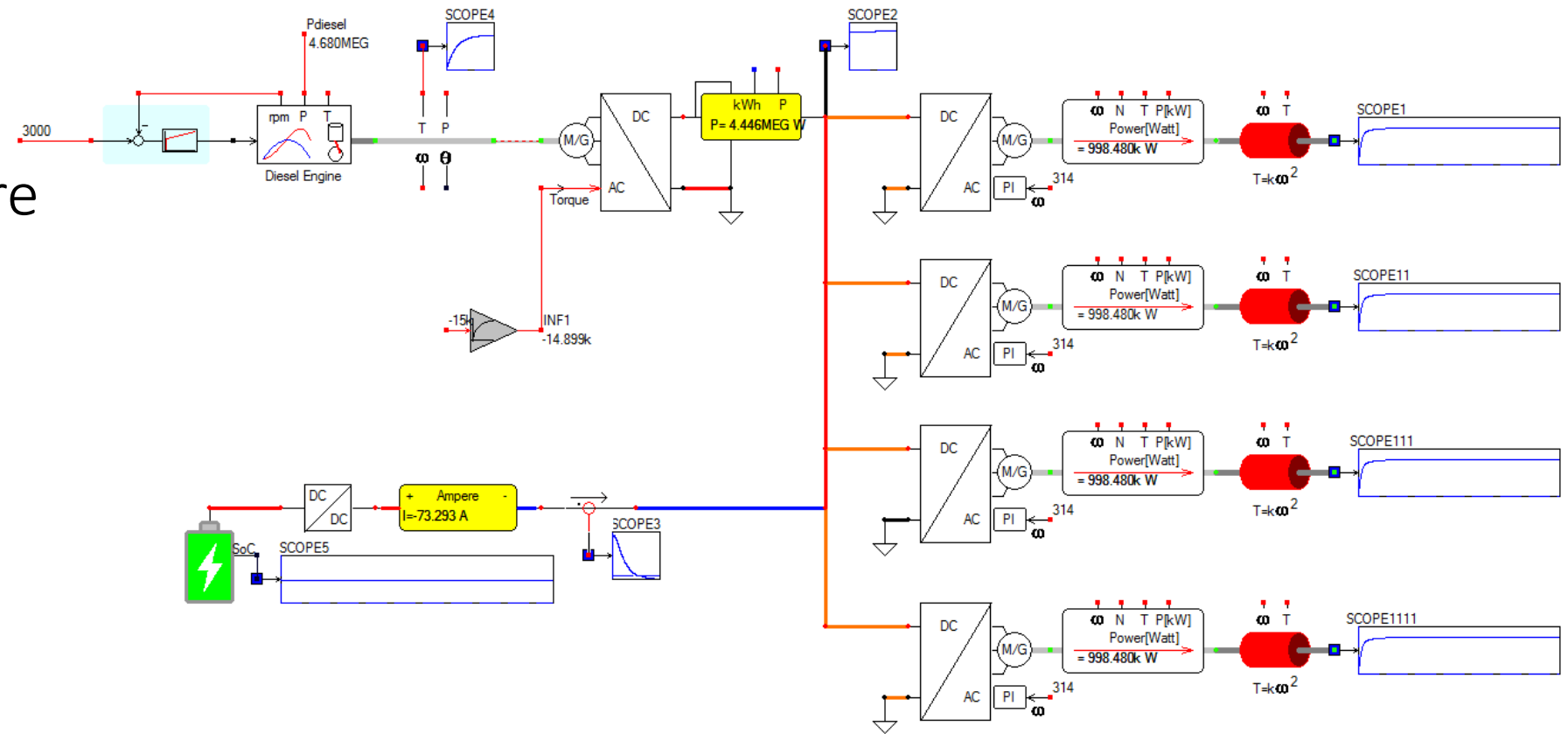Electric and Hybrid Marine Expo Europe, June 21,22,23 2022

Contents

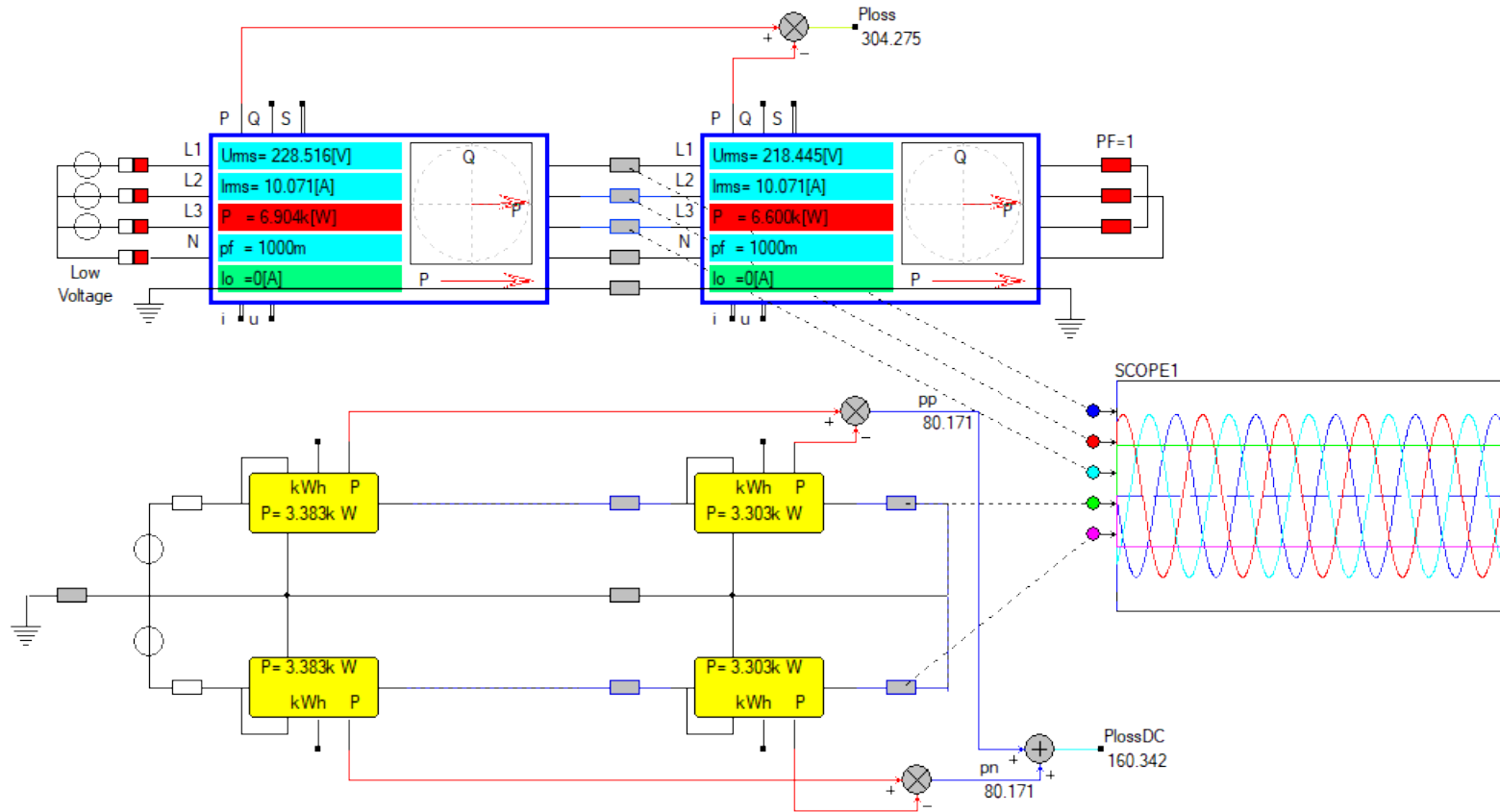- DC grid structure
- Control
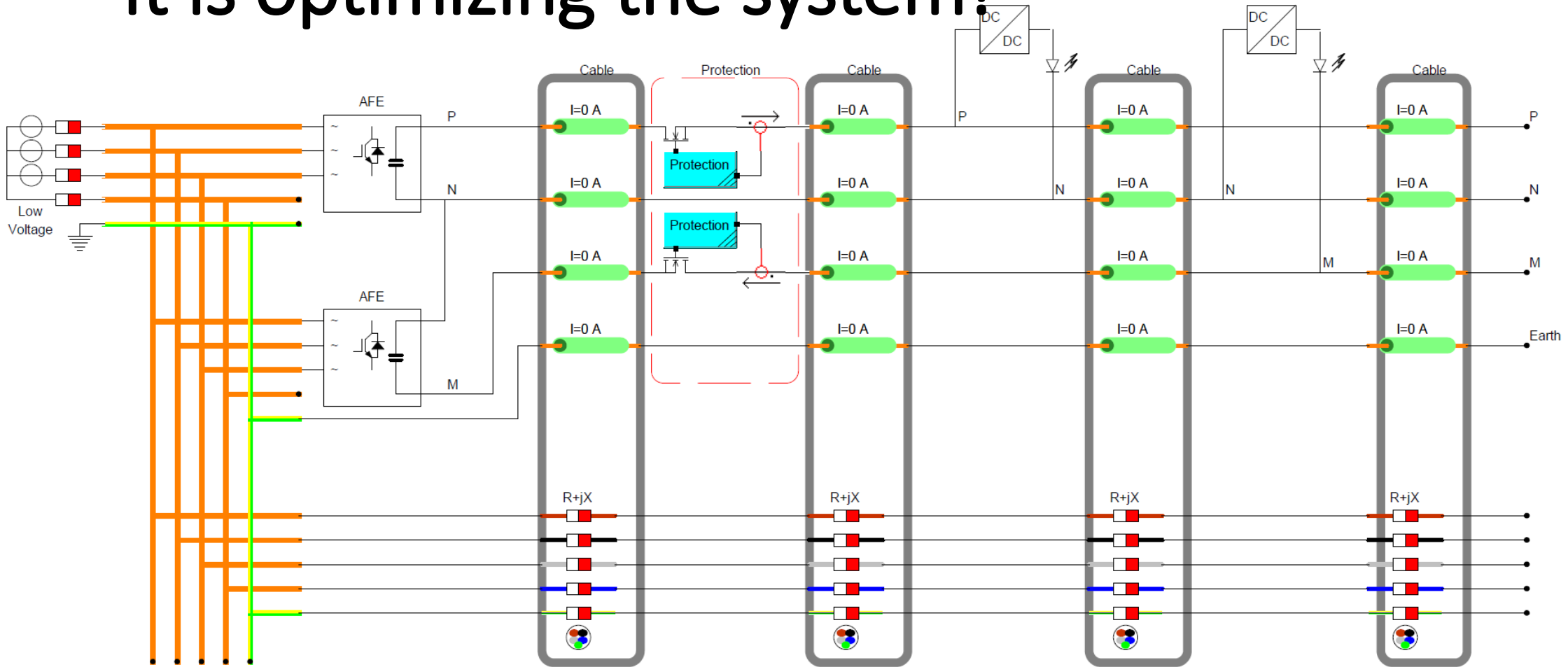- Switching
- Protection
- Stability

DC grid structure?

Structure of the DC Grid

Why do we need a DC Grid?
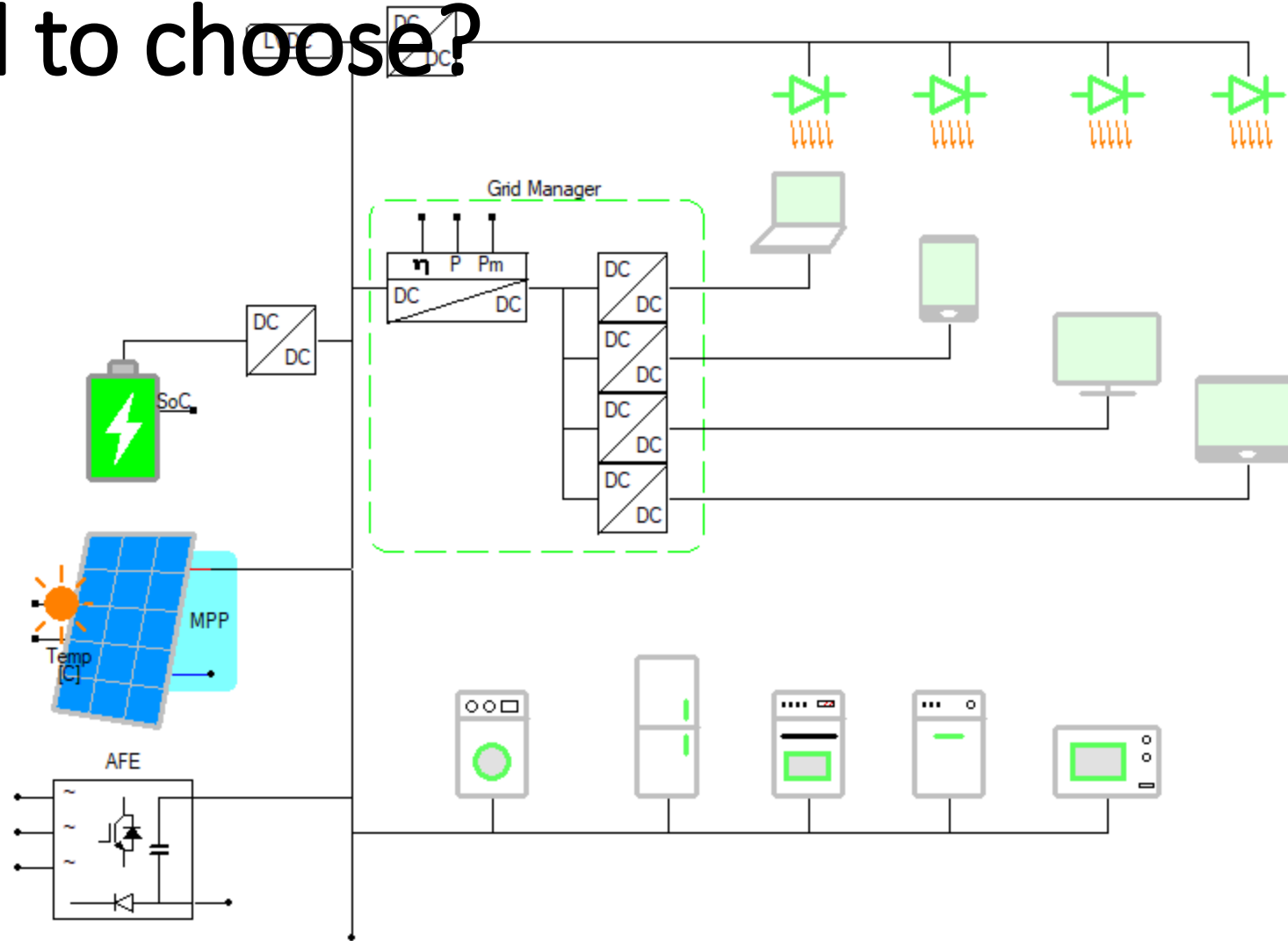# Lower losses is not the reason why we choose DC!

It is not about optimizing components
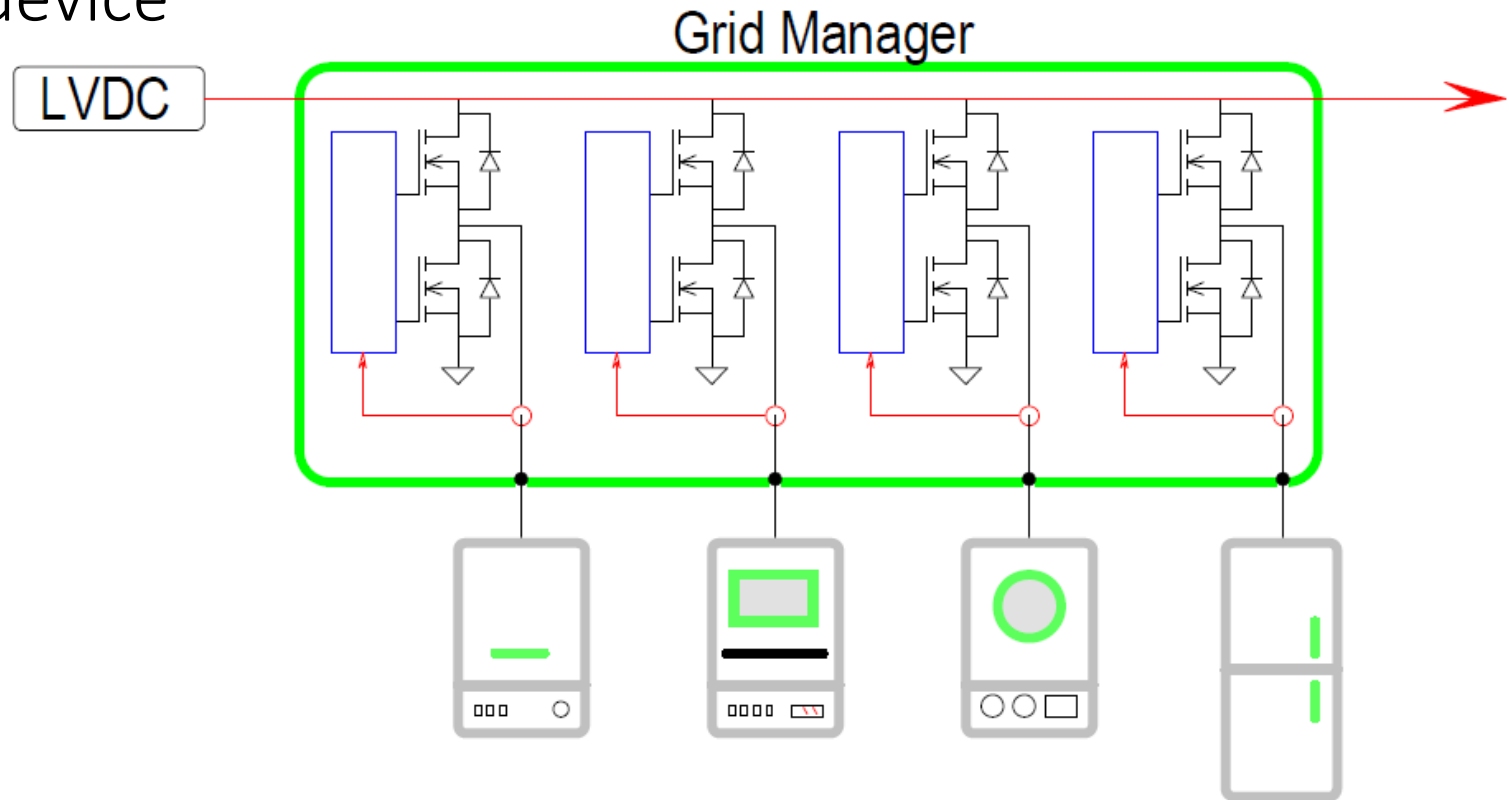# It is optimizing the system!

Which grid to choose?
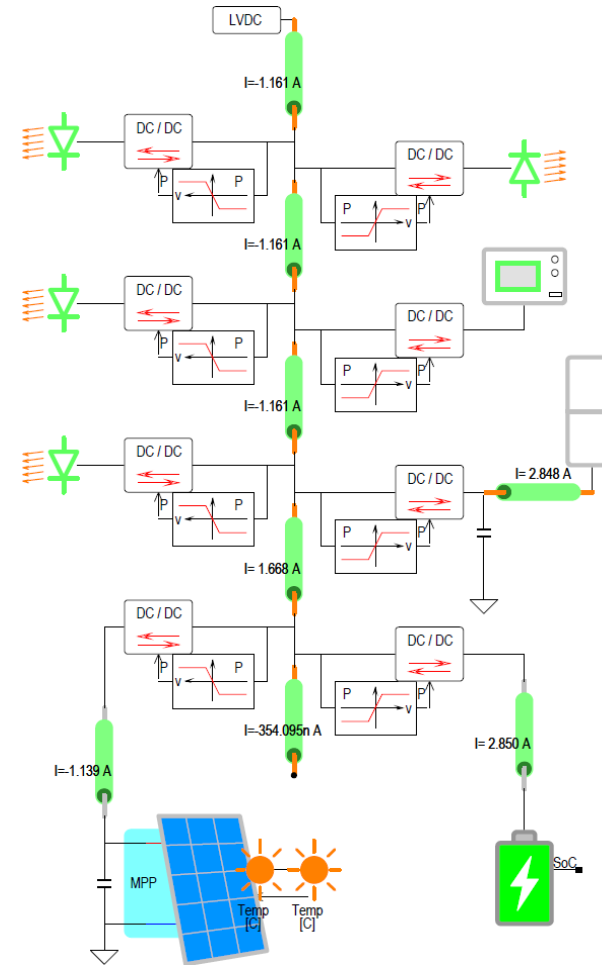
- Centralized
- Decentralized

Centralized DC Grid with Grid Manager

- All control in one device
- Control of Power
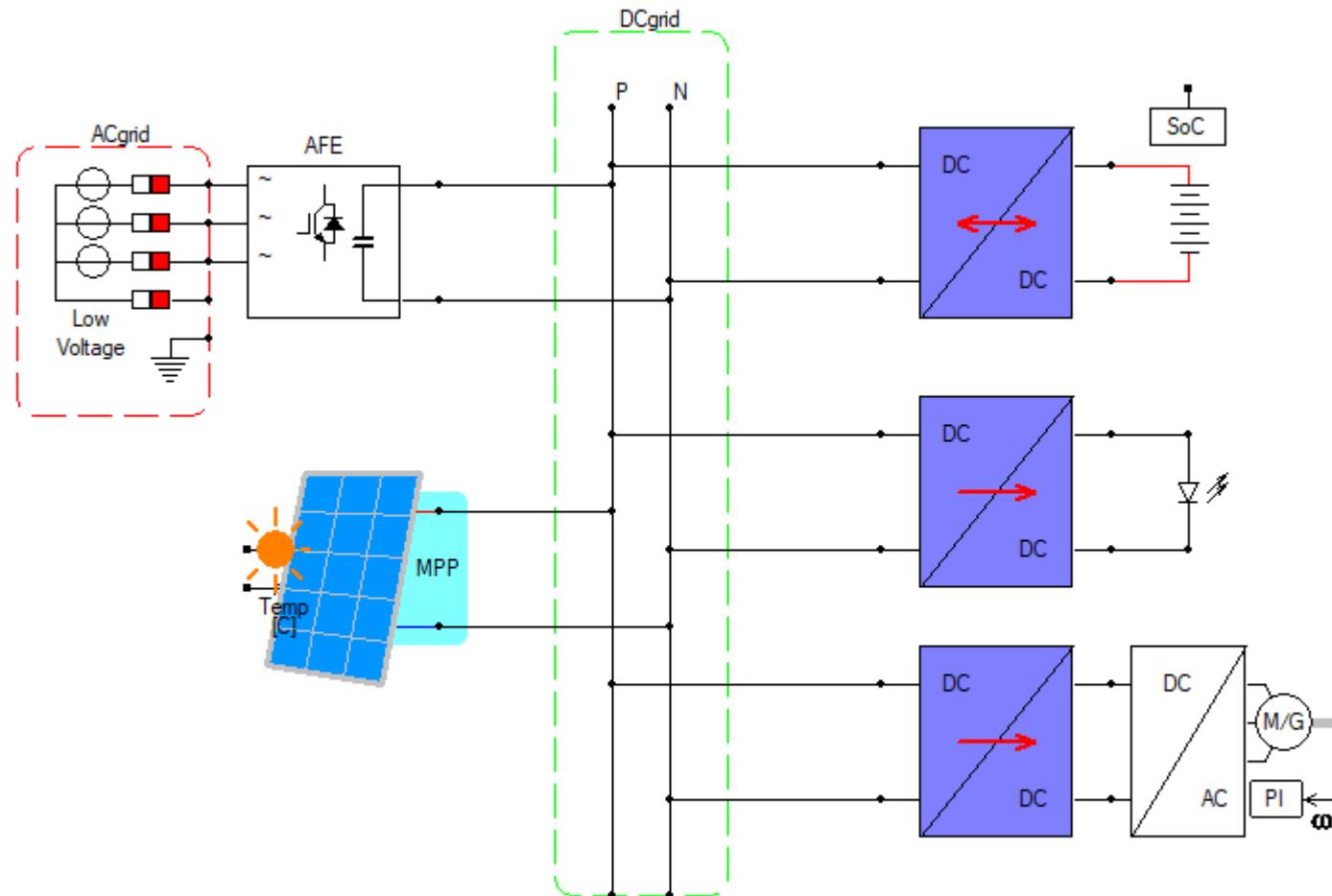- Breaker
- Inrush limiter
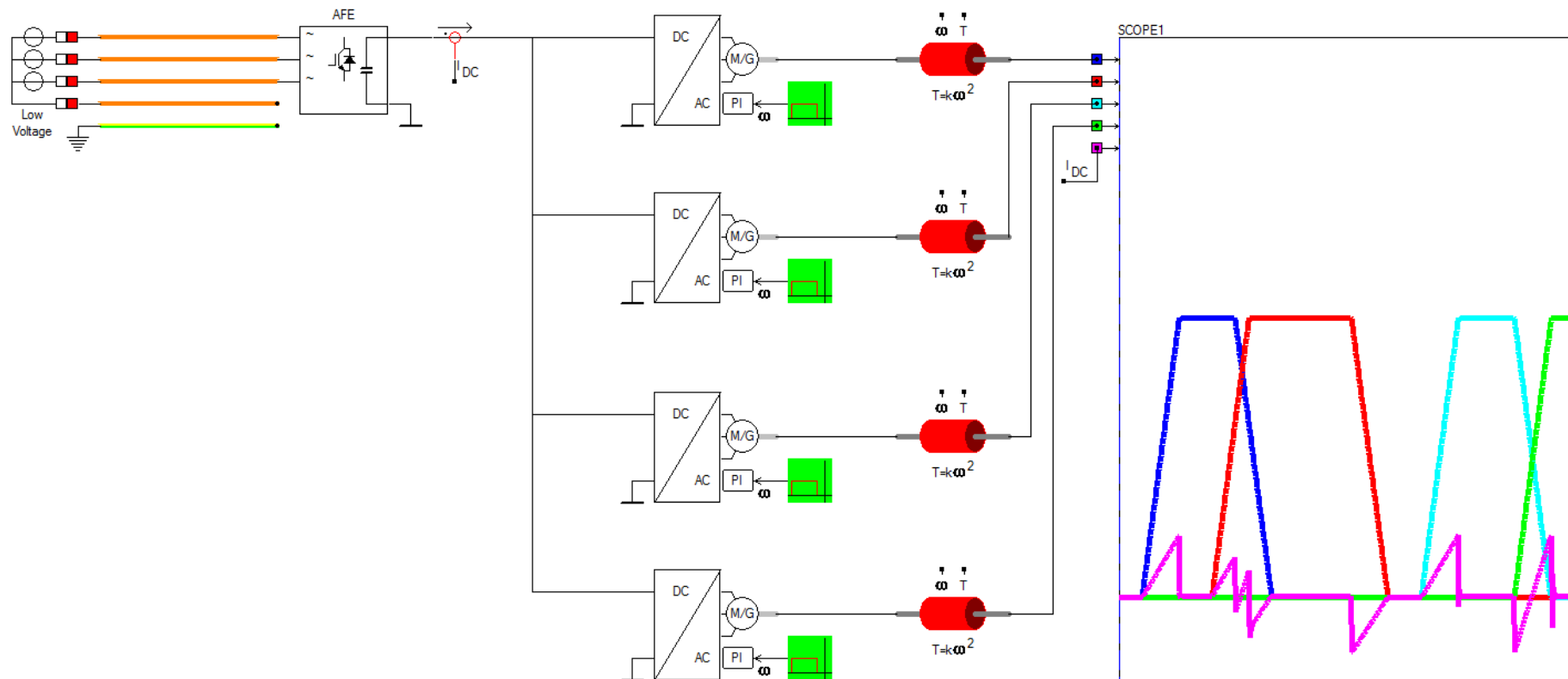
Decentralized DC Grid with Droop Control

- Droop control per appliance
- DCDC converter per appliance

Producers and Consumers are directly coupled

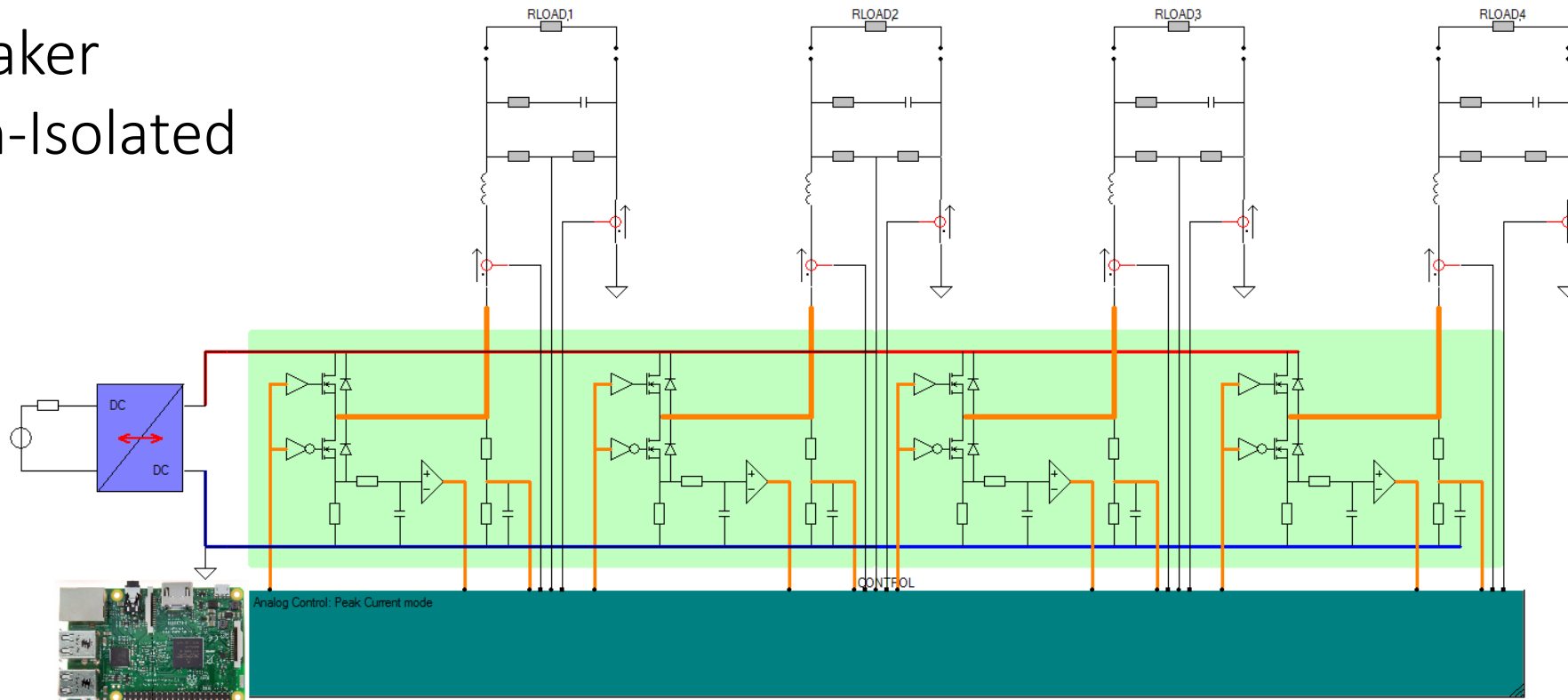# Exchange of Drive and Brake Energy

Switching in the DC grid?

What type of switches do exist,
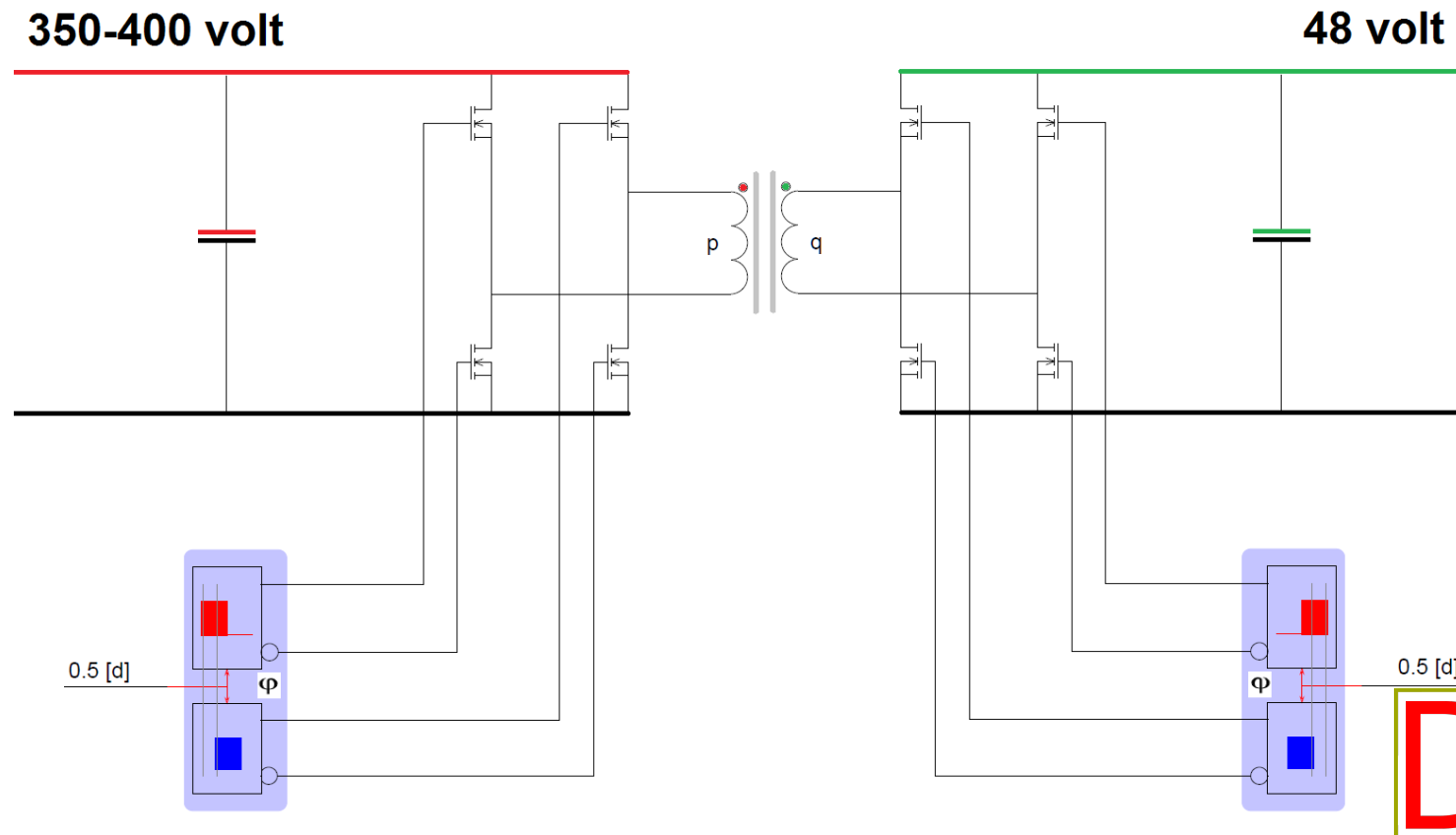if they do exist at all?

Grid Manager contains multiple Synchronous Buck Converters

- power flow
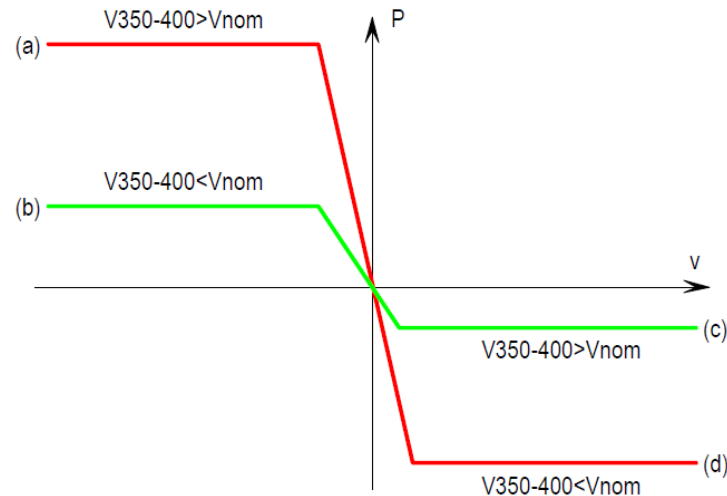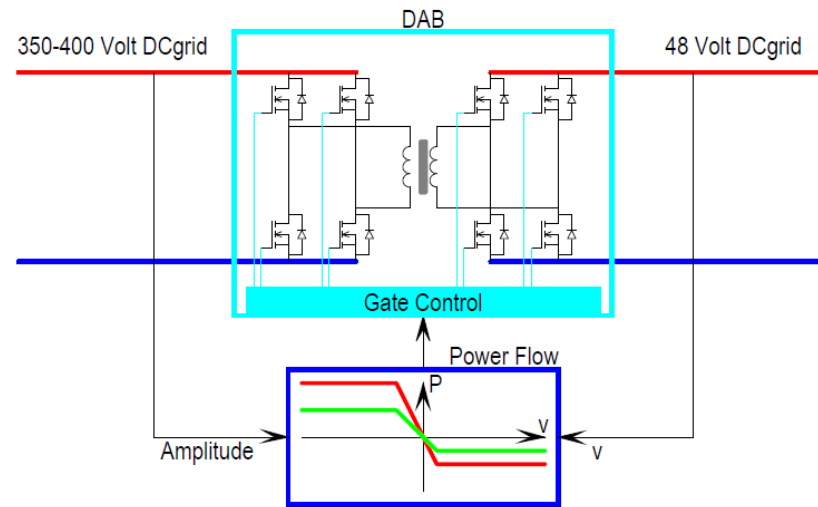- Current Limited
- Breaker
- Non-Isolated

Dual Active Bridge is Isolated

- Bidirectional power flow
- Current Limited
- Breaker
- Isolated
- DC transformer

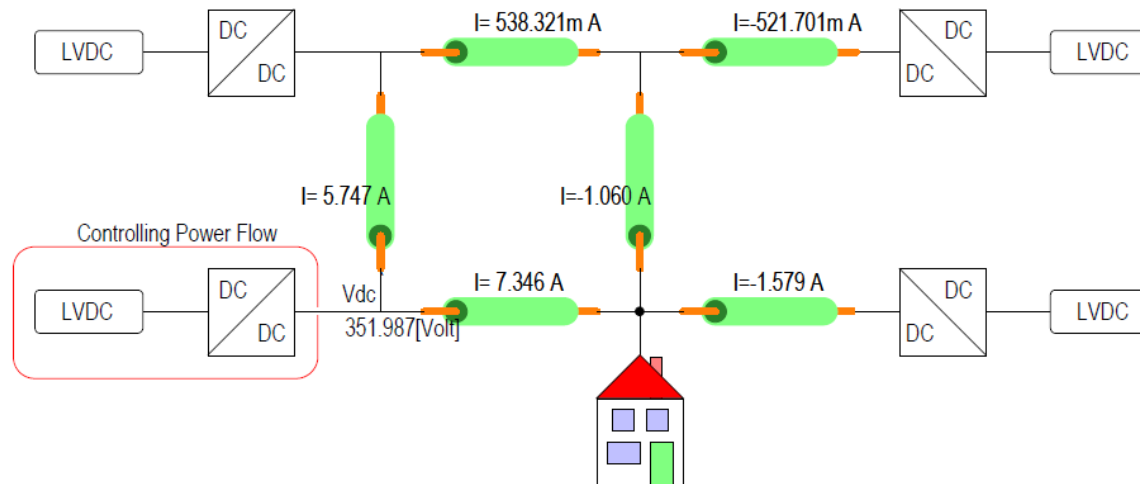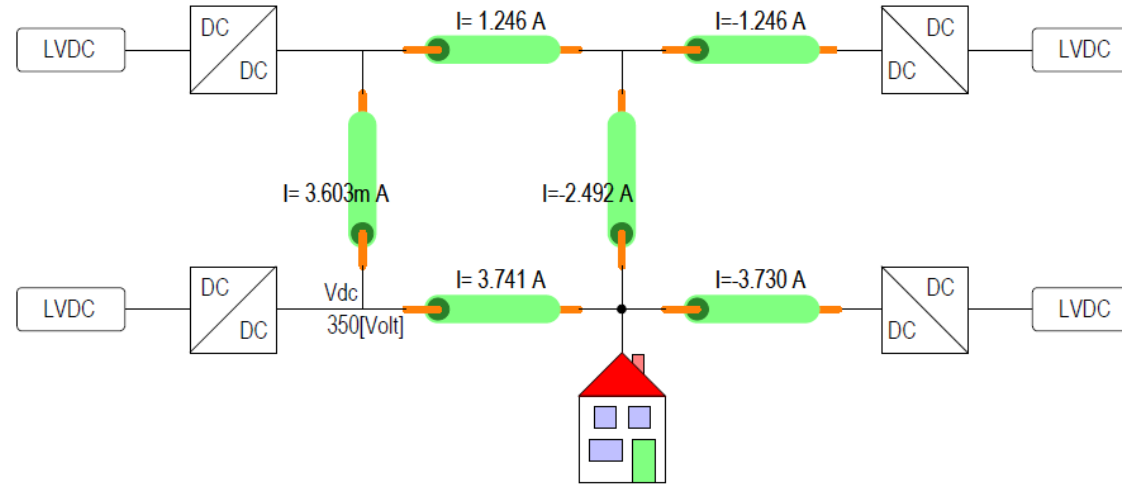# Connecting two DC grid with different voltage levels

DC grid control?

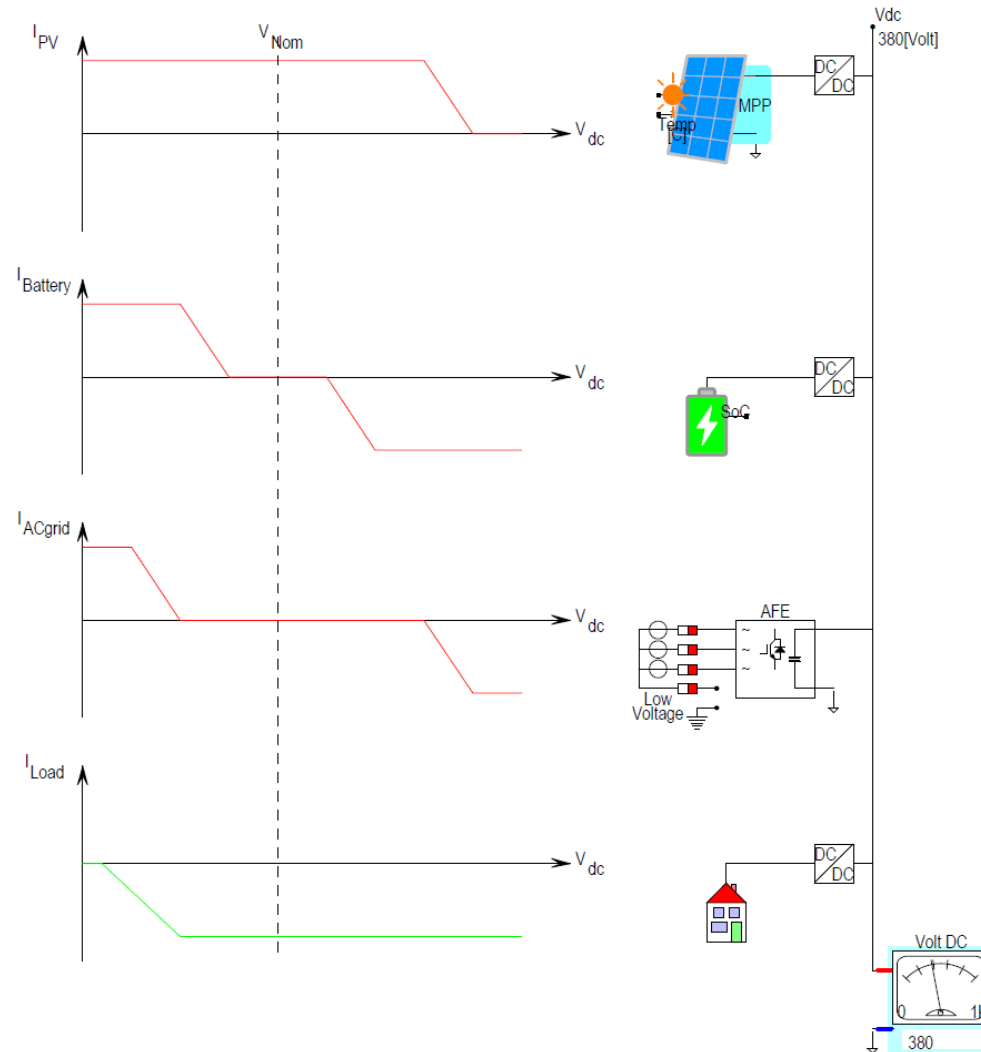Control and Power Congestion Management
in the DC Grid

Control the current in a Meshed grid

- Nodal voltage defines current flow
- DCDC converters have losses

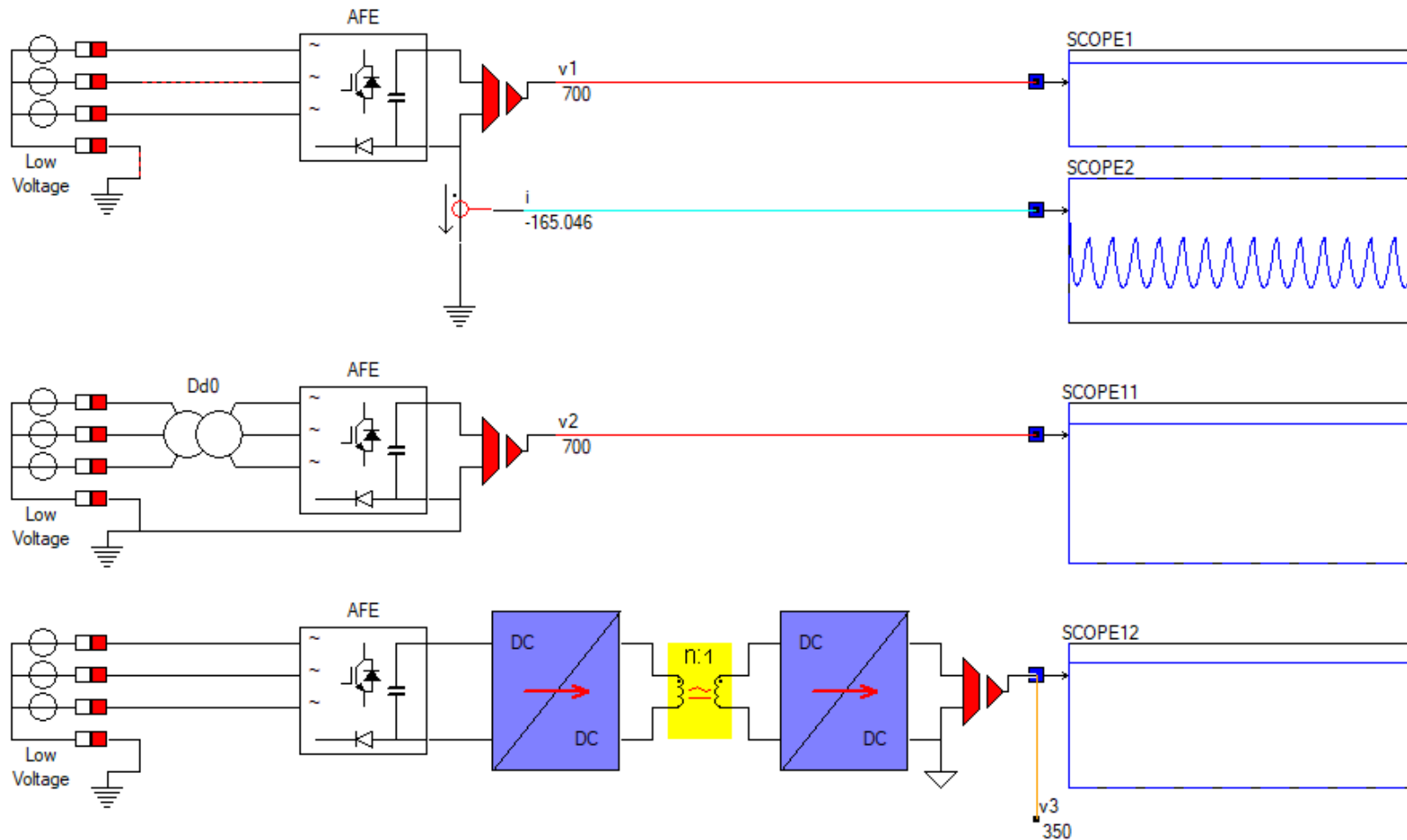# Droop Control regulates in a decentralized grid

- Controlled current flow per appliance
- Islanding operation
- No communication required
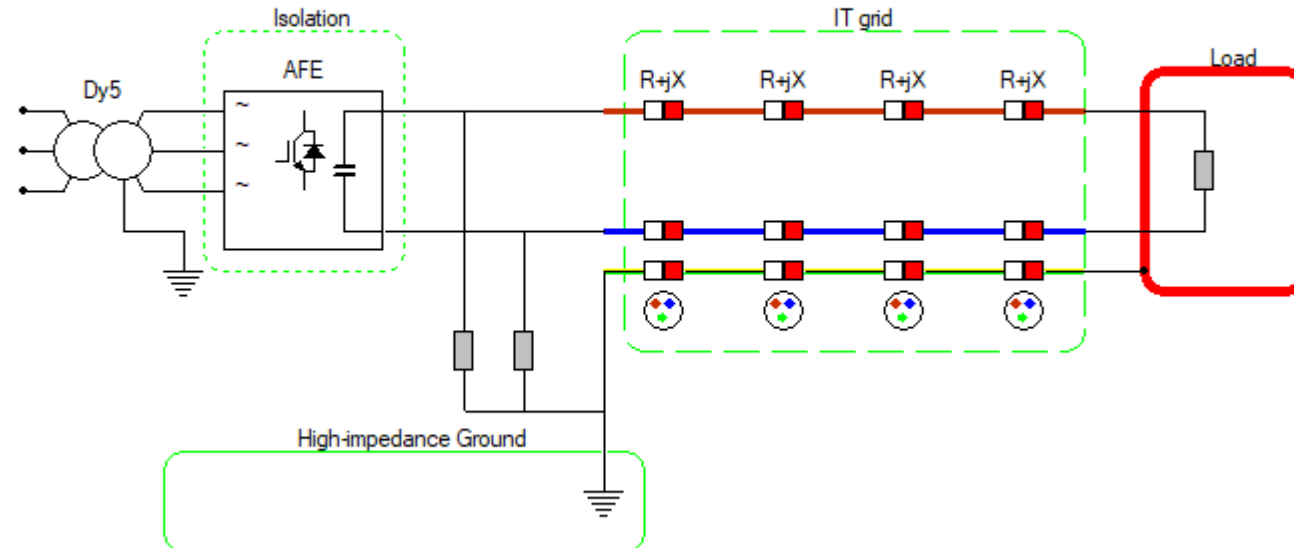
DC grid selectrivity and protection?

Protection and/or selectivity
in the DC Grid?

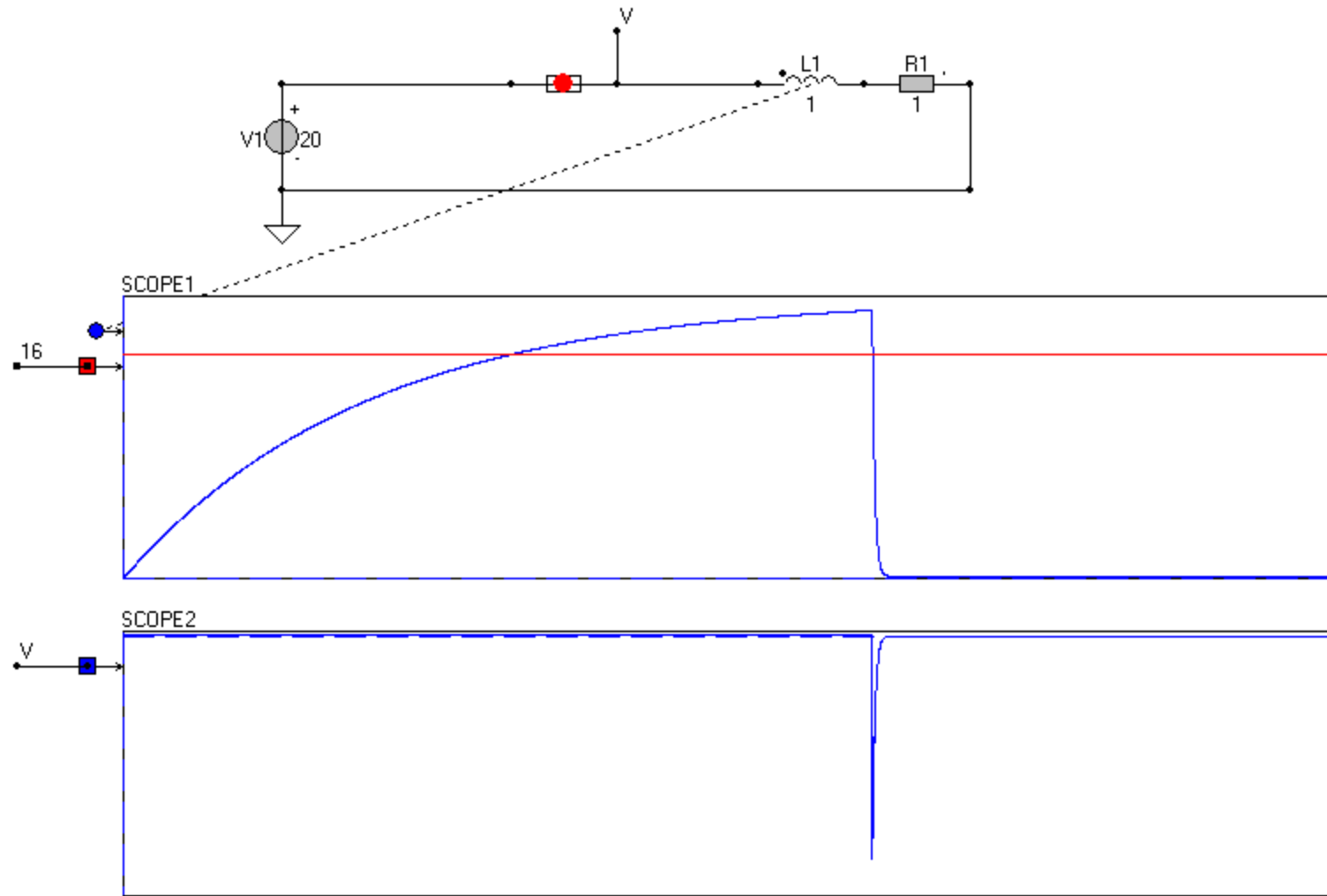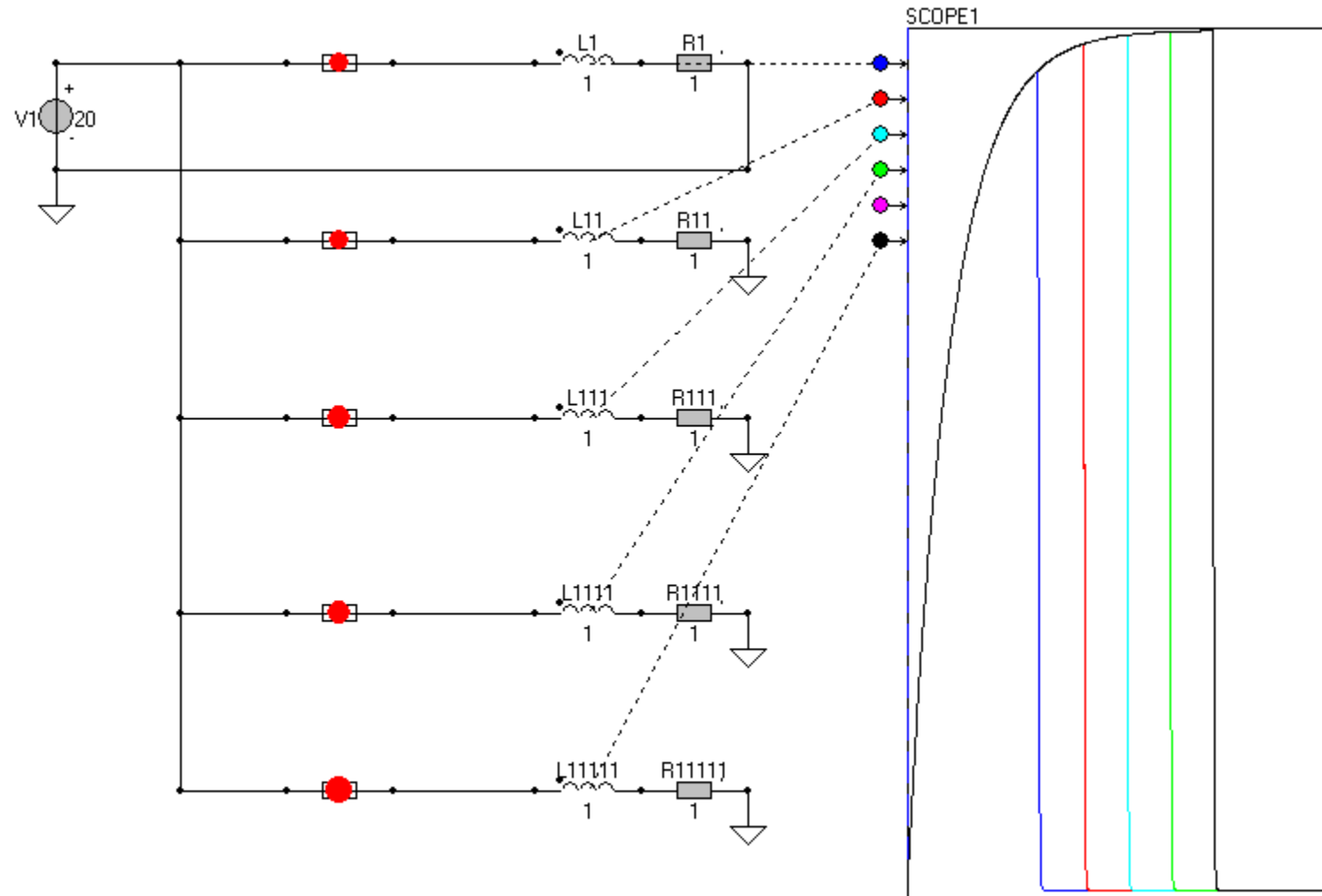# When grounding, the DC grid has to be isolated from the AC grid

Grid system?

- You can choose an isolated Grid IT to implement earth leakage detection,
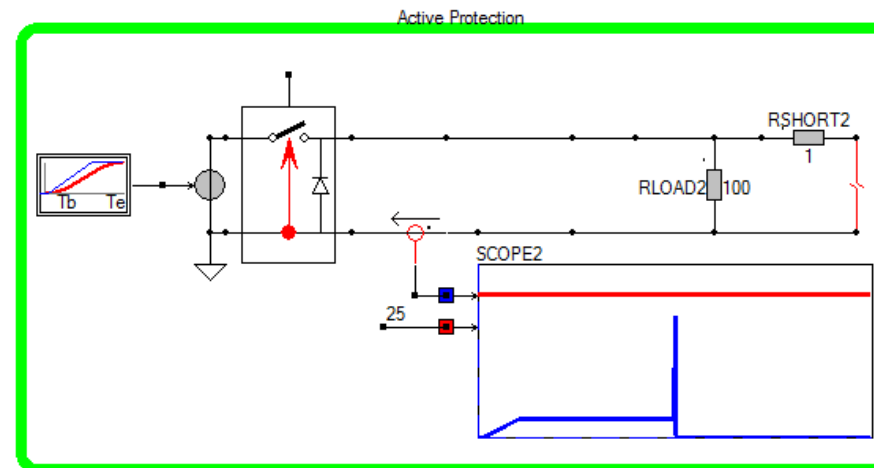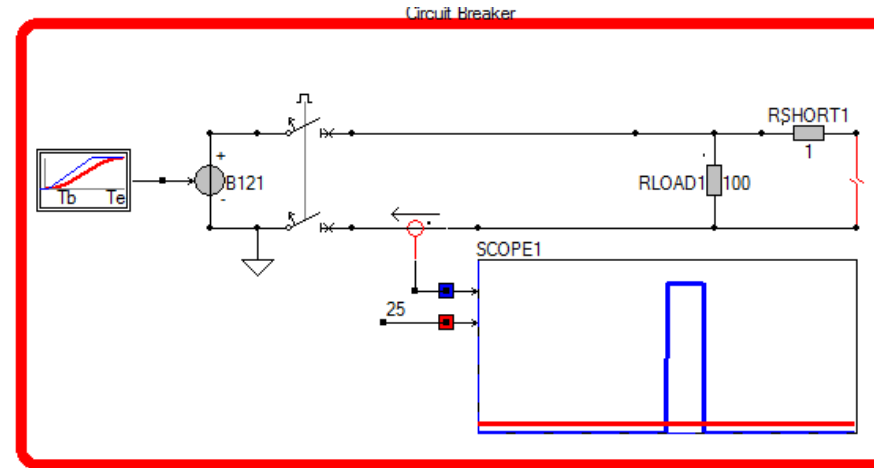- but your grid is floating!

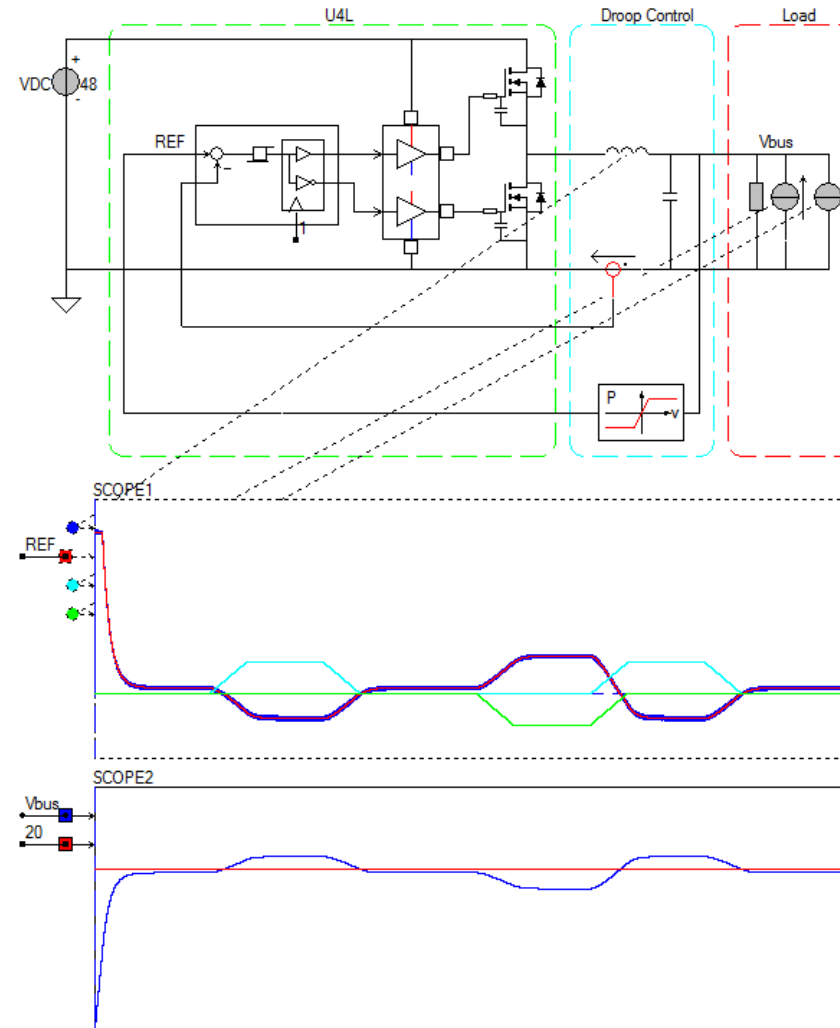# Fuse?

Fuse?

RoCoC Rate of Change of Current

DC grid stability?
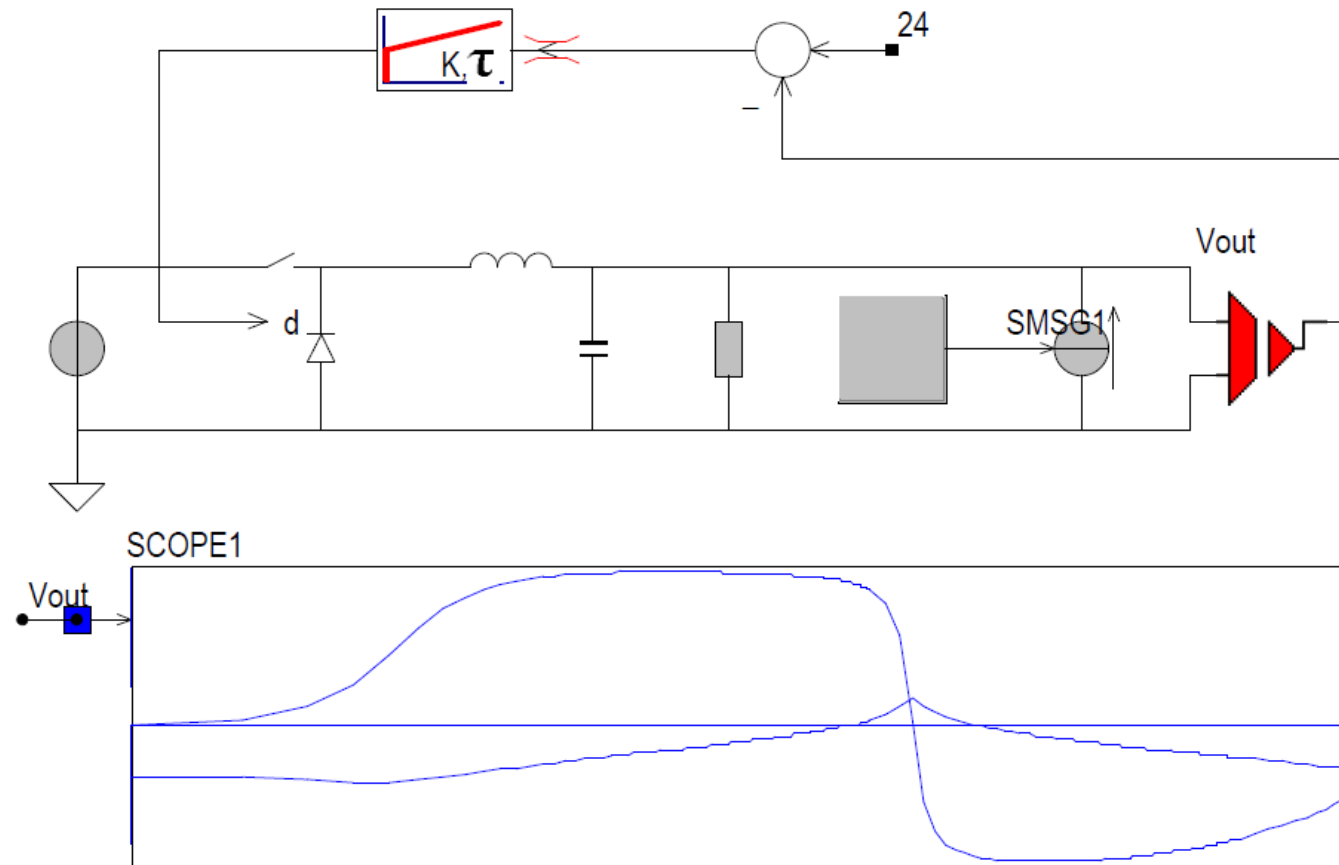
How to predict and ensure stability in the DC Grid

Static stability depends in Droop Control Characteristics

- Droop characteristic
- per appliance
- Low Bandwidth
- Stand alone operation

Dynamic stability depends on input and output impedance
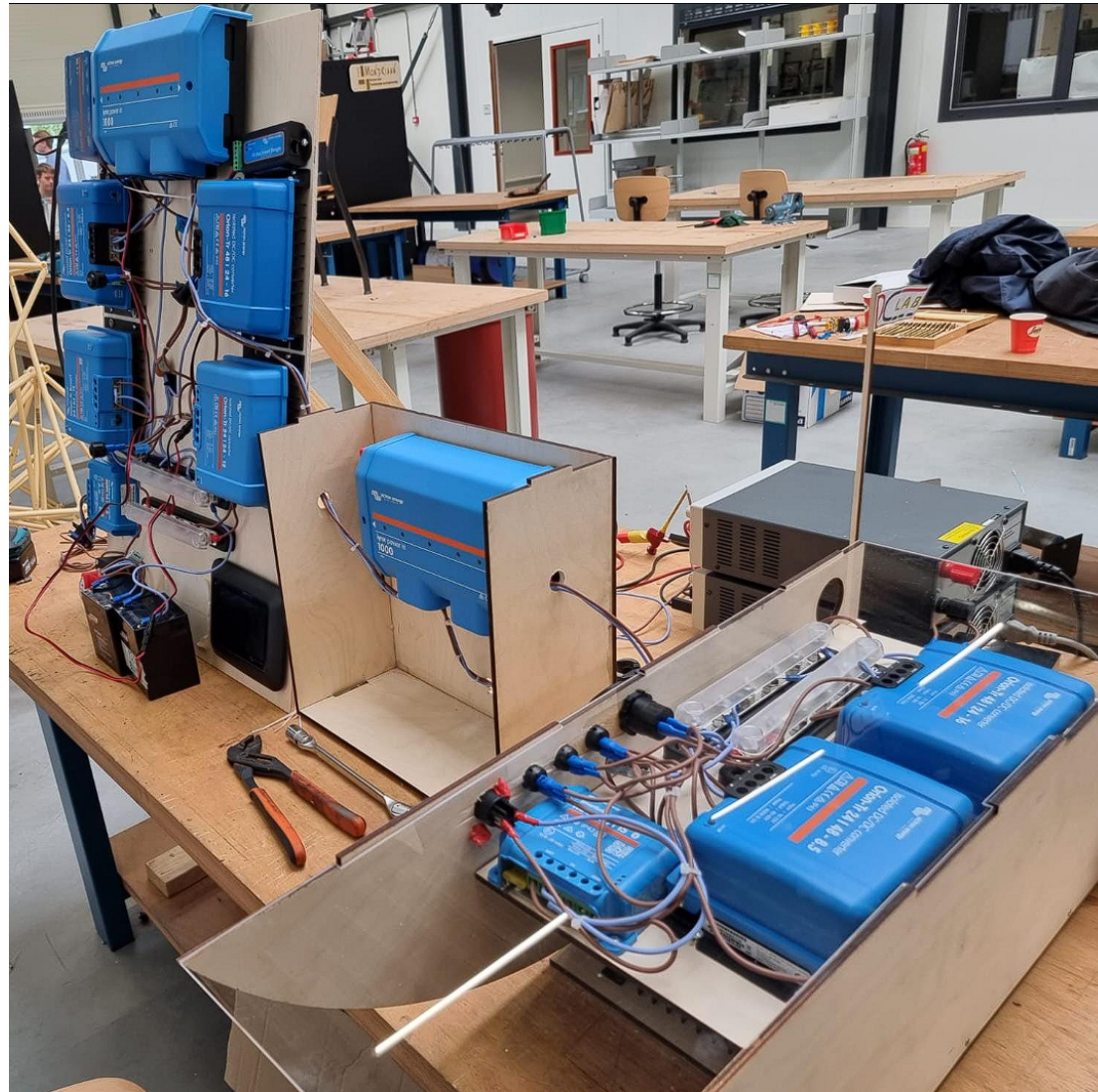
- Zout < Zin
- Middlebrooks
  Stability Criterion

laakhaven
Example inner harbor Laakhaven

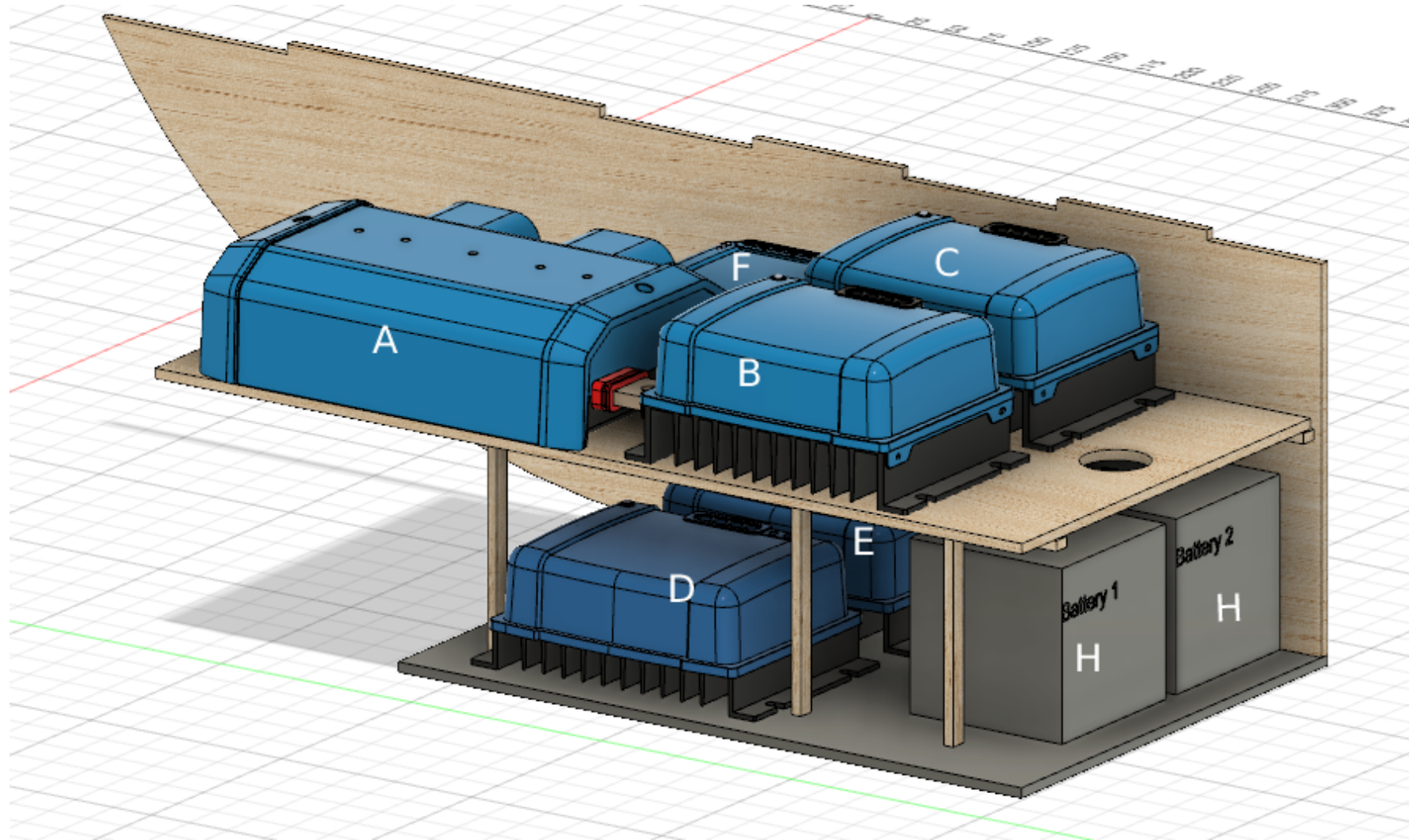DC Distribution between small ships

DC LAB

Ships connected to the AC grid system set up
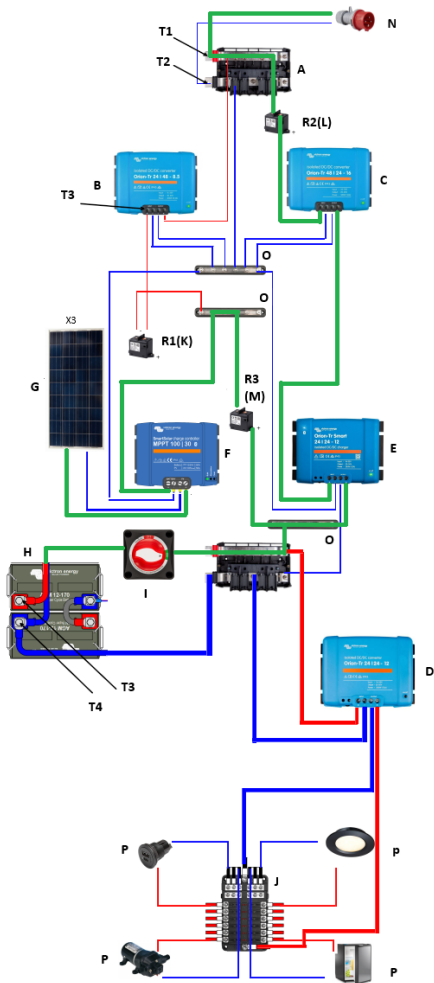
Power supply at the Laakhaven
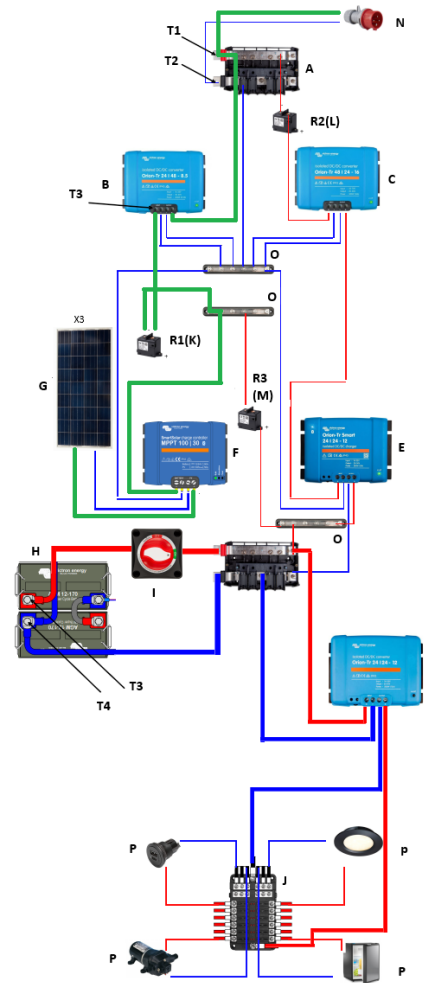
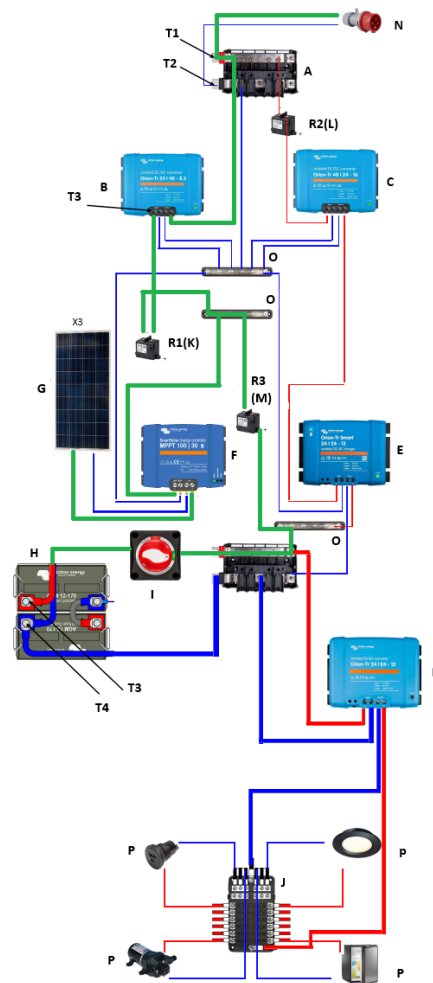# Ships connected to the AC grid System
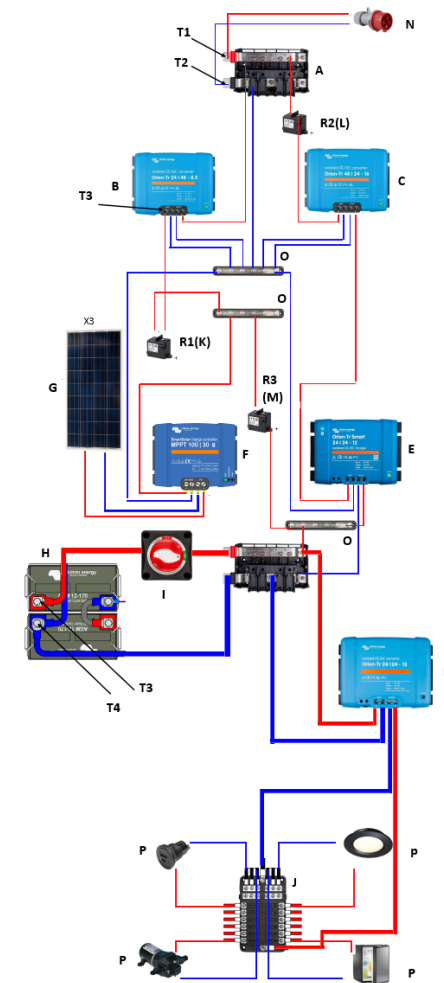
Wiring AC connections
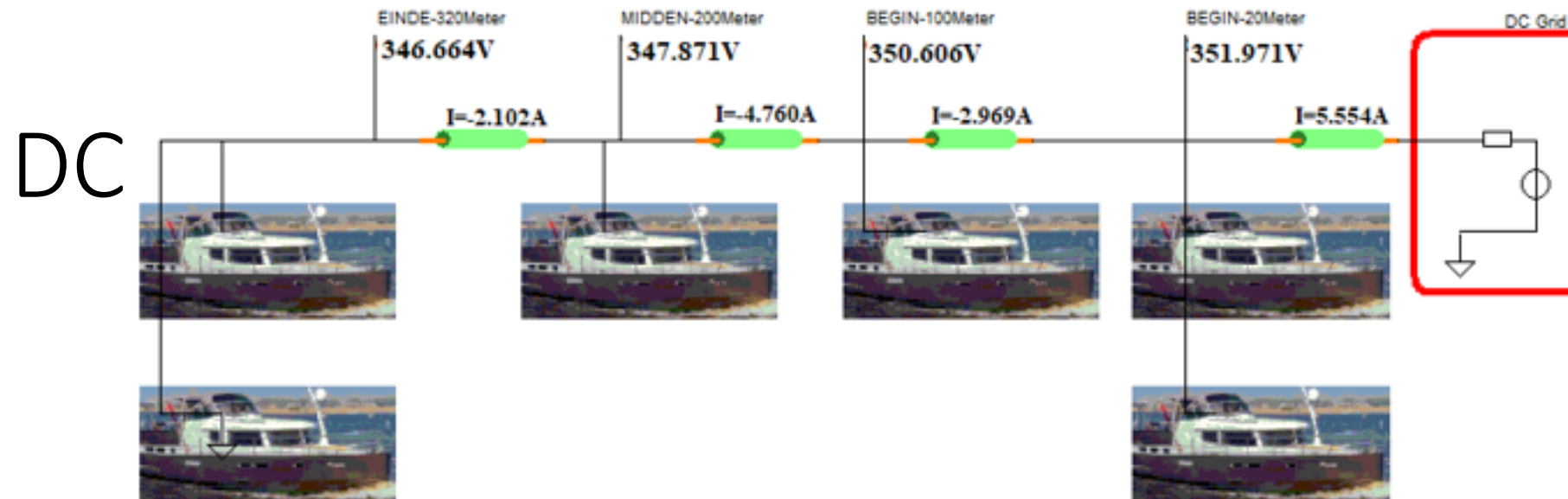

Charge (Grid and PV)

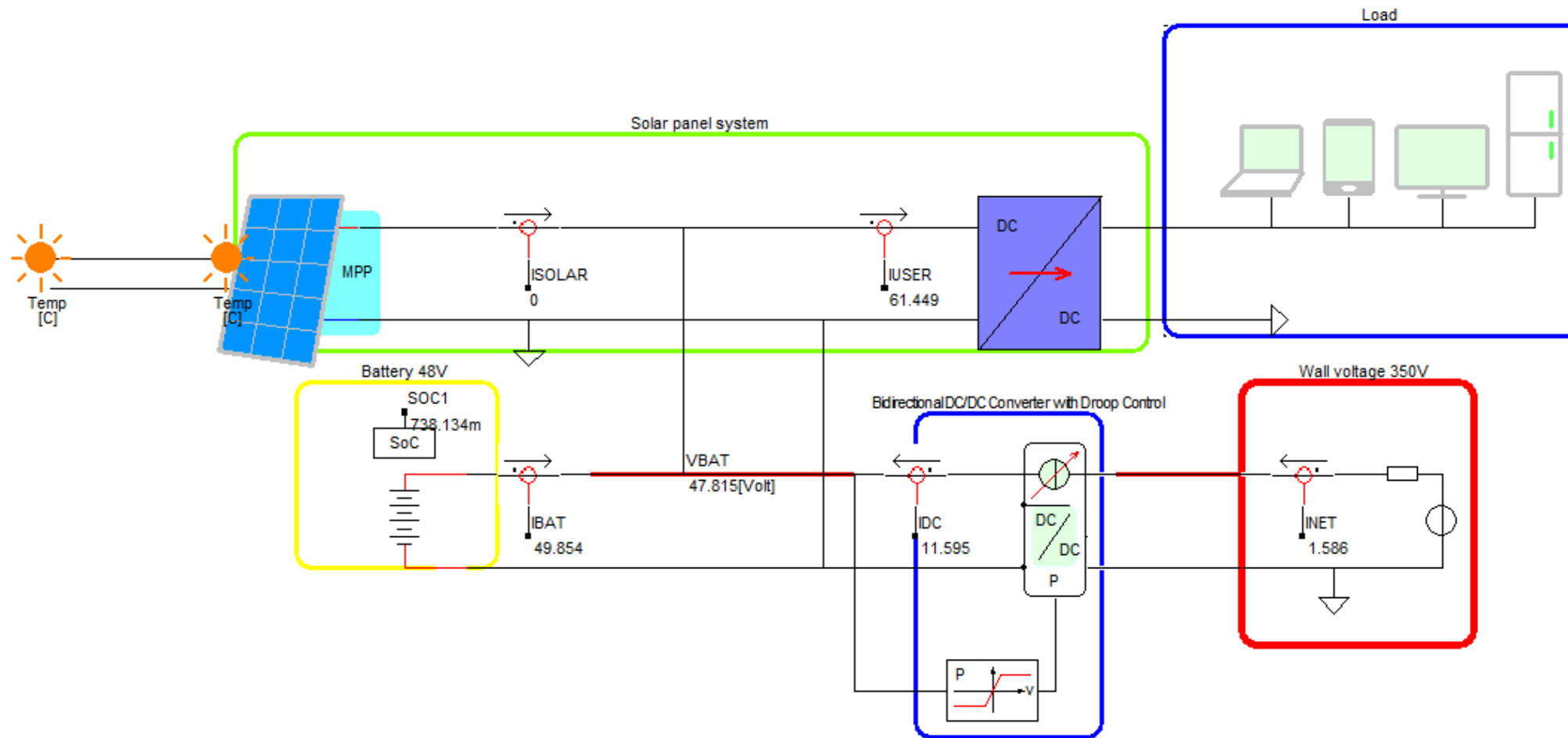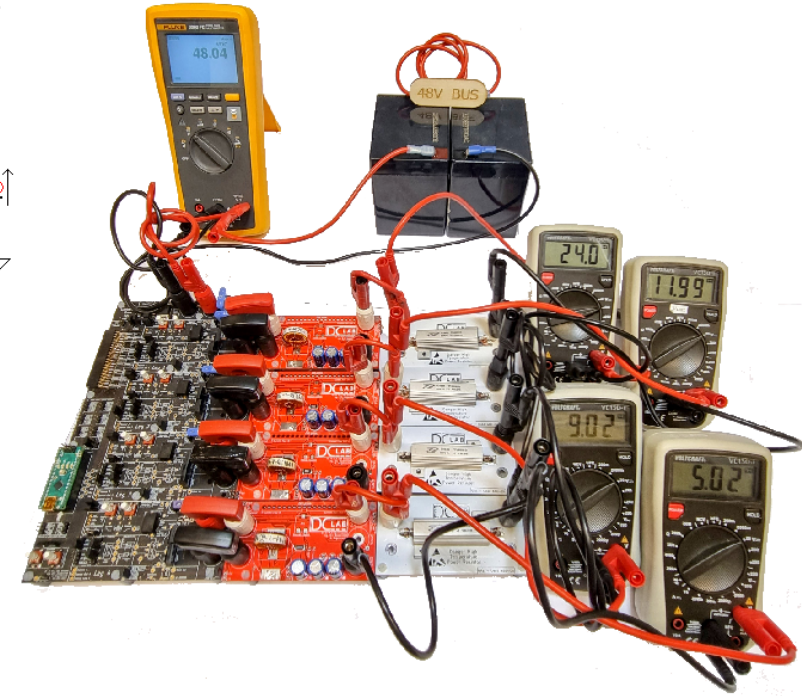Return grid (PV only)
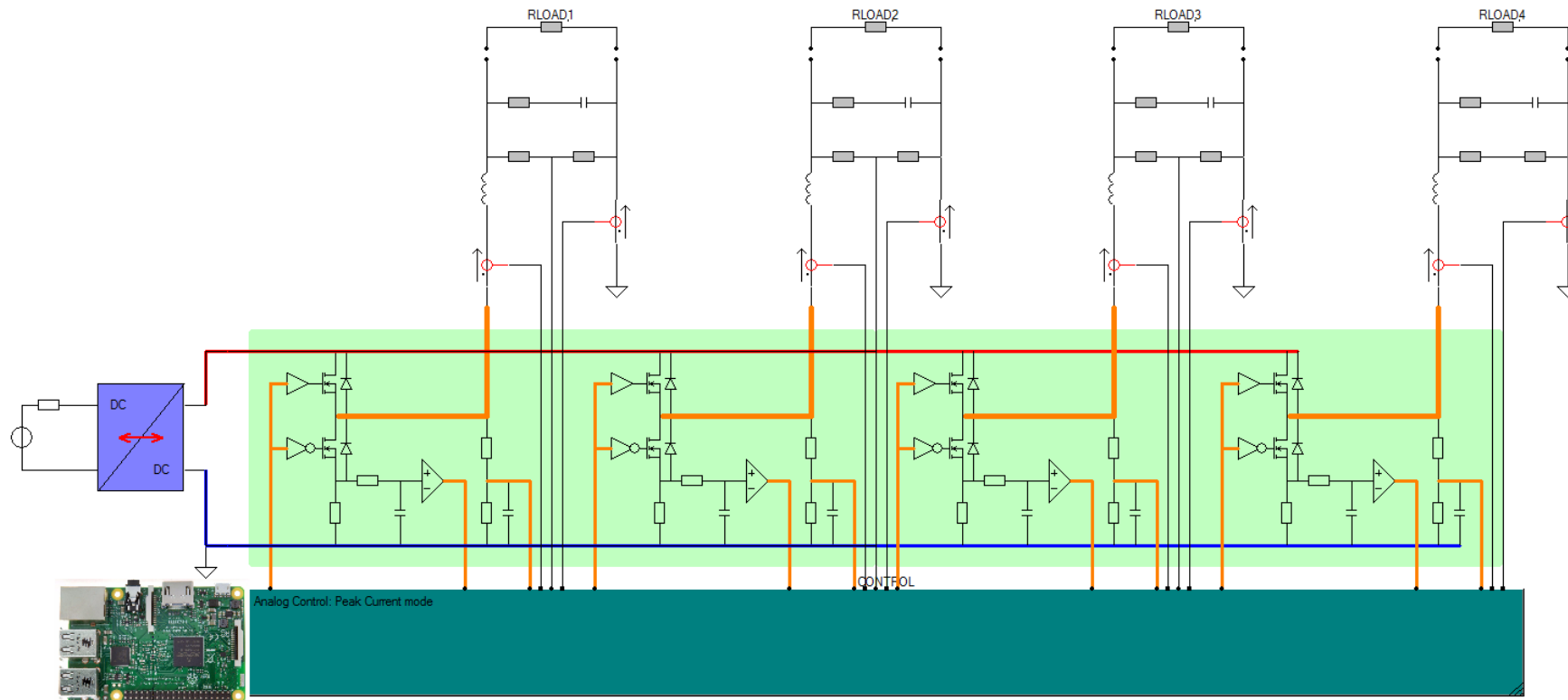
Return grid (PV and battery)

Fully charged

Ships connected to the DC grid

DC Droop control per ship

Single Grid Manager connected to the DC grid.

Conclusion: DC Grid: Protect or Control?

- Centralized or Decentralized
- Control
- Protection
- Stability

Thanks for your attention!   www.dc-lab.org