Grid Congestion and the Role of Power Electronics and Battery Storage

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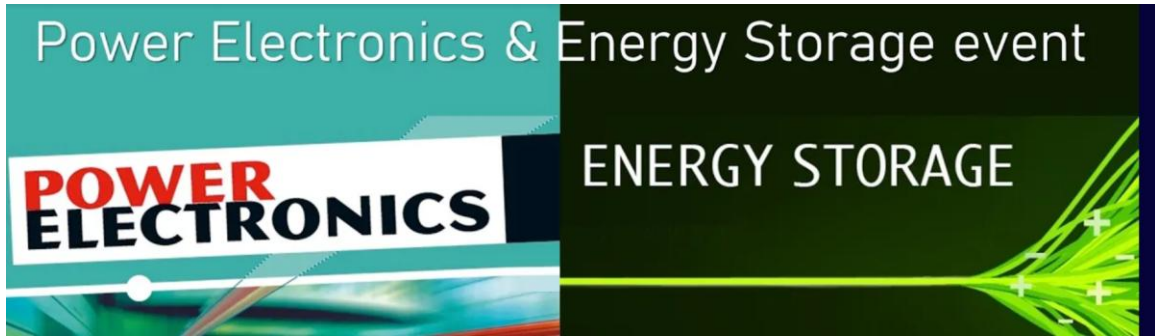
The Hague University of Applied Sciences

Power Electronics & Energy Storage Event, Mai 27, 2026

THE HAGUE UNIVERSITY OF APPLIED SCIENCES

DC LAB

Caspoc



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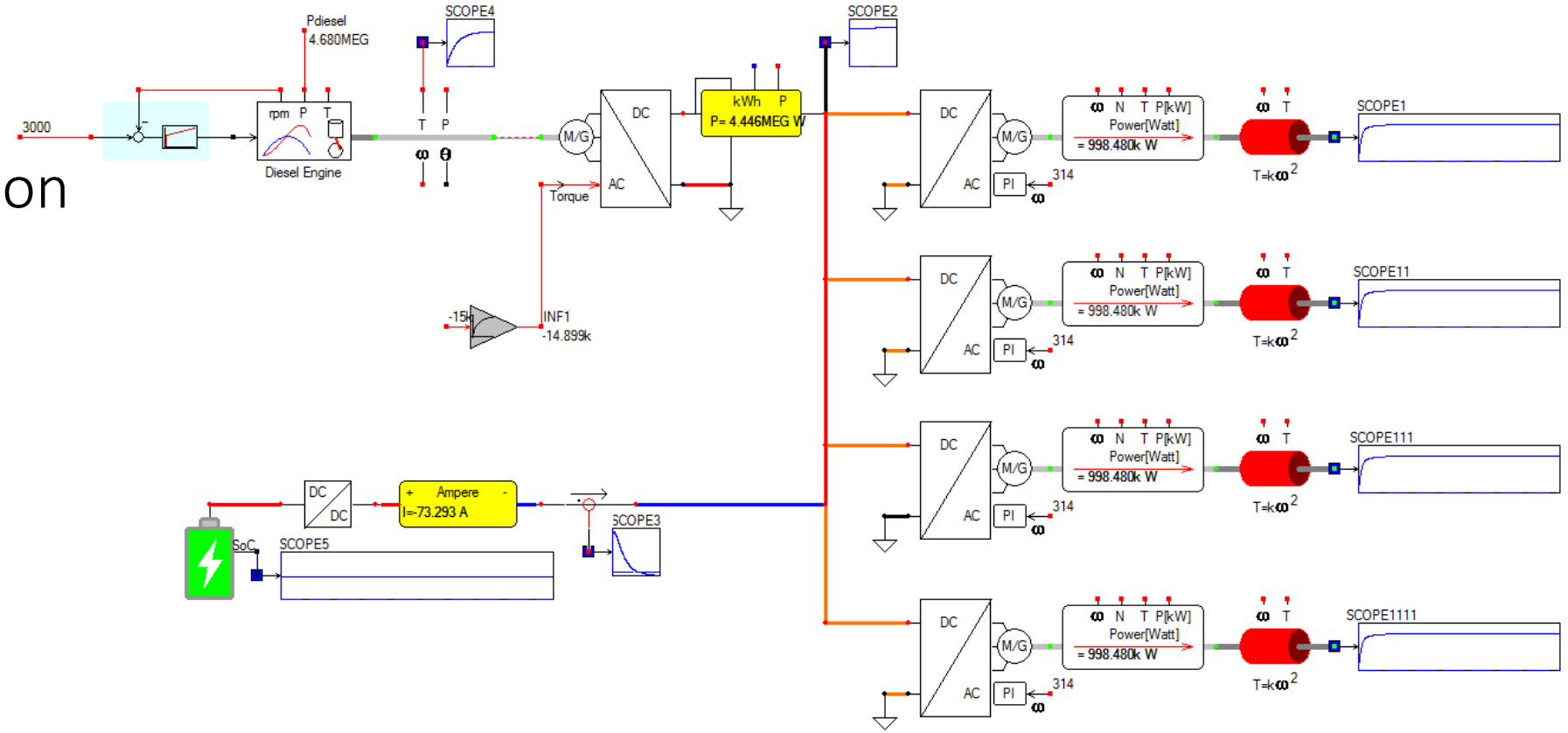
Contents

- Power Generation
- AC DC
- Profiles
- Tools
- Simulation
- Congestion
- DC Grids



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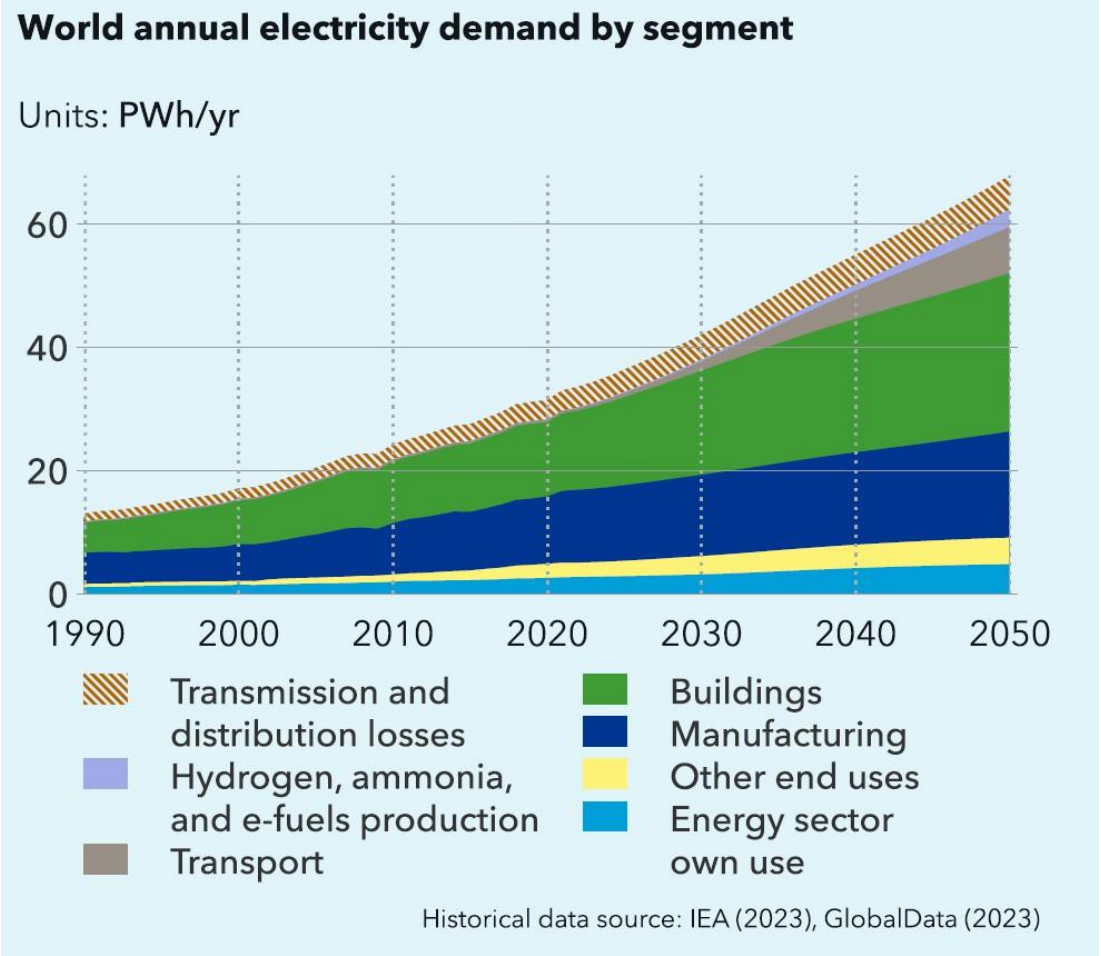
World Annual Electricity Demand



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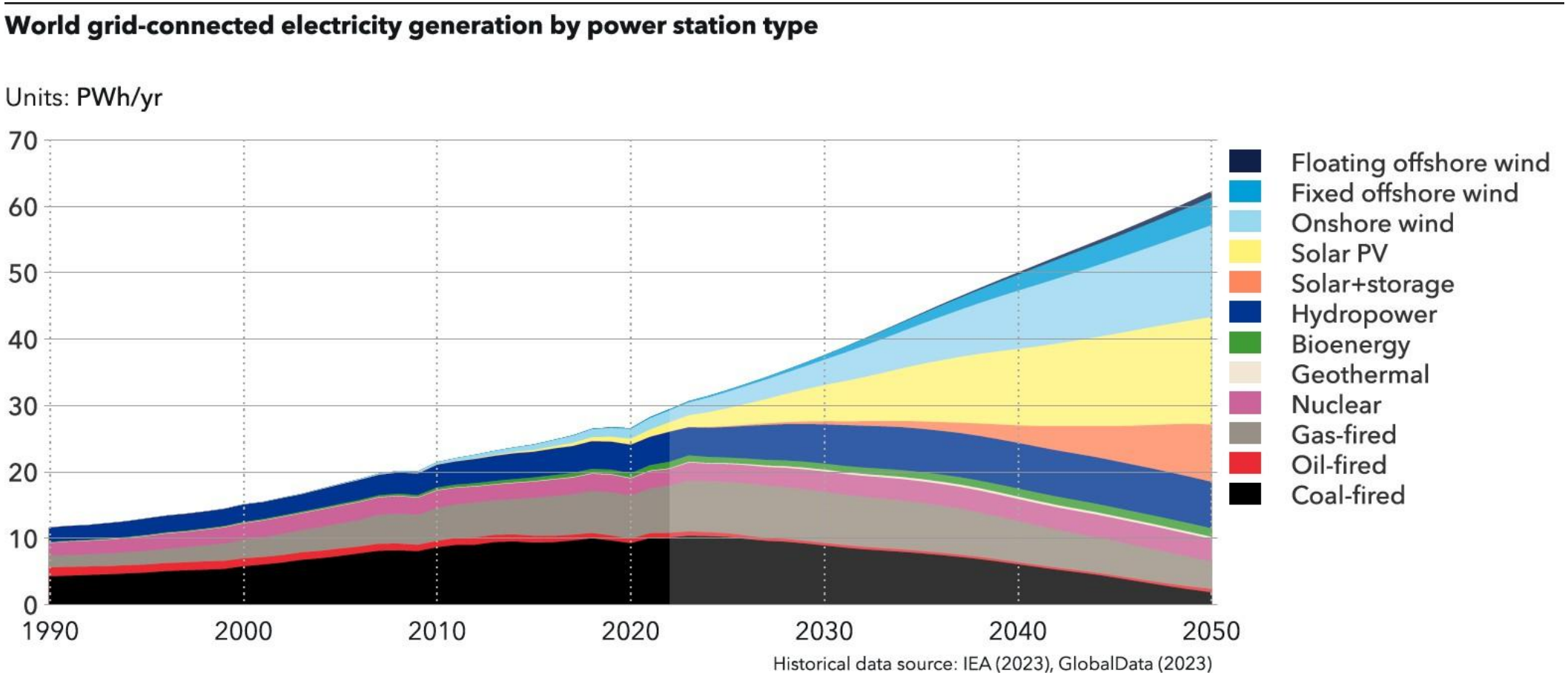
World Electricity Generation Power Station



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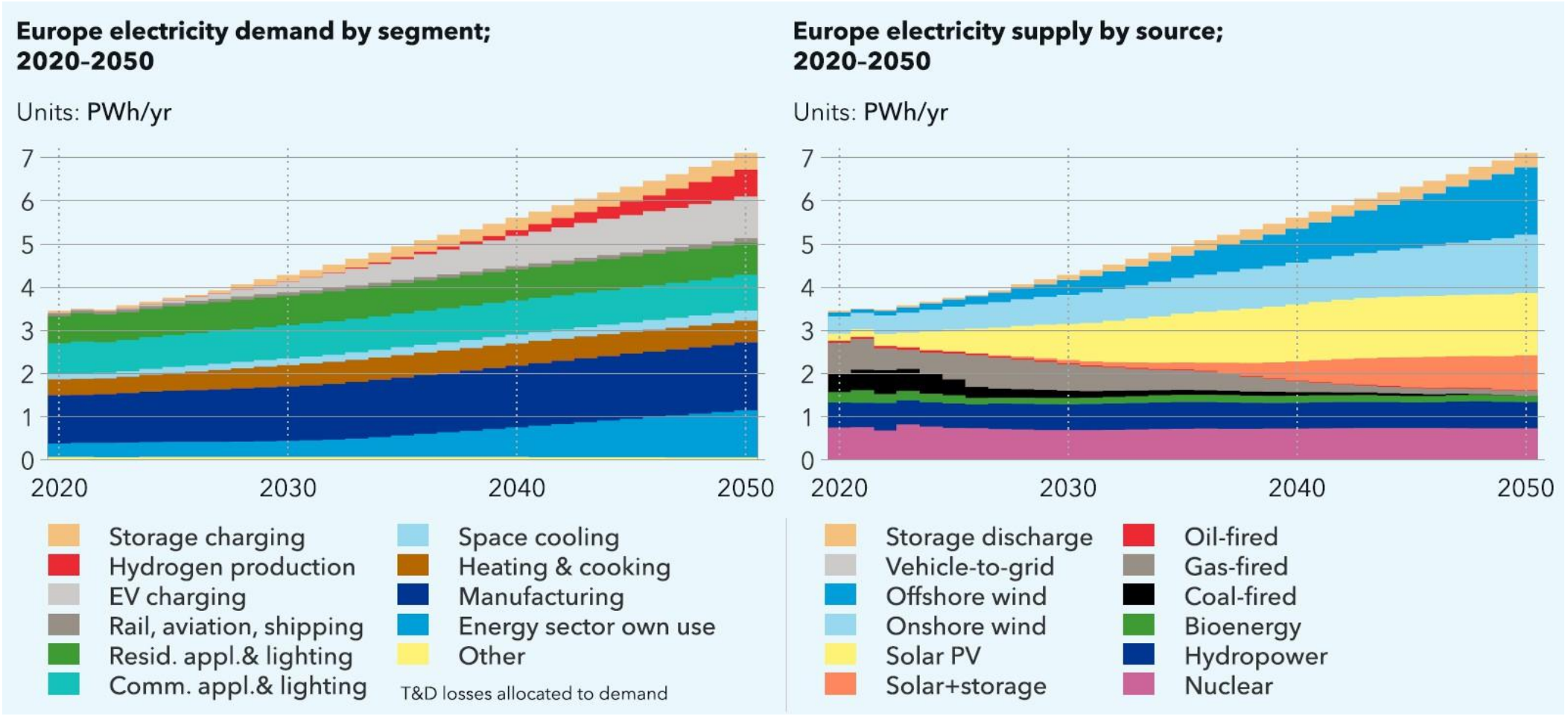
Production Demand Europe 2020 - 2050



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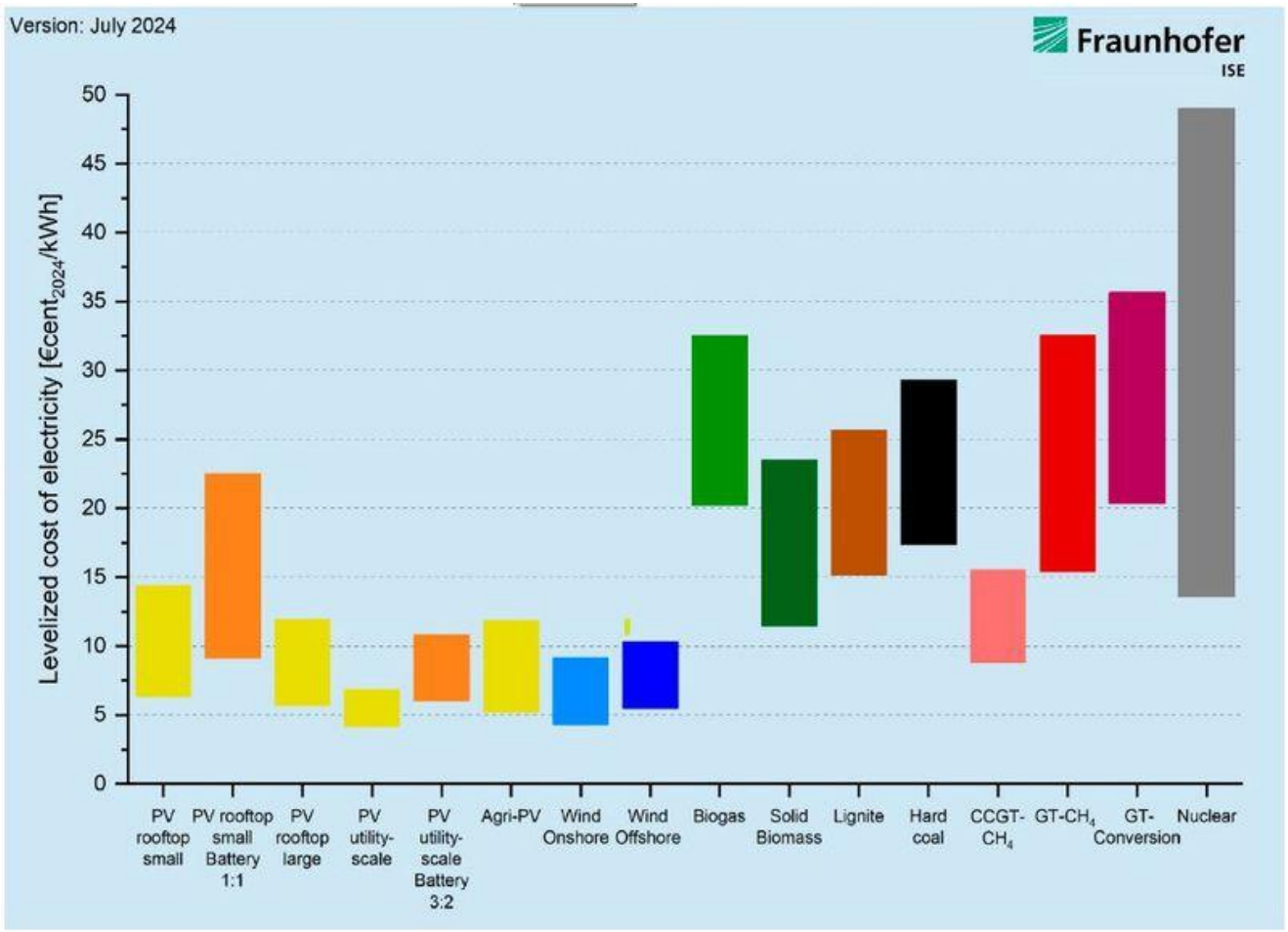
Production cost



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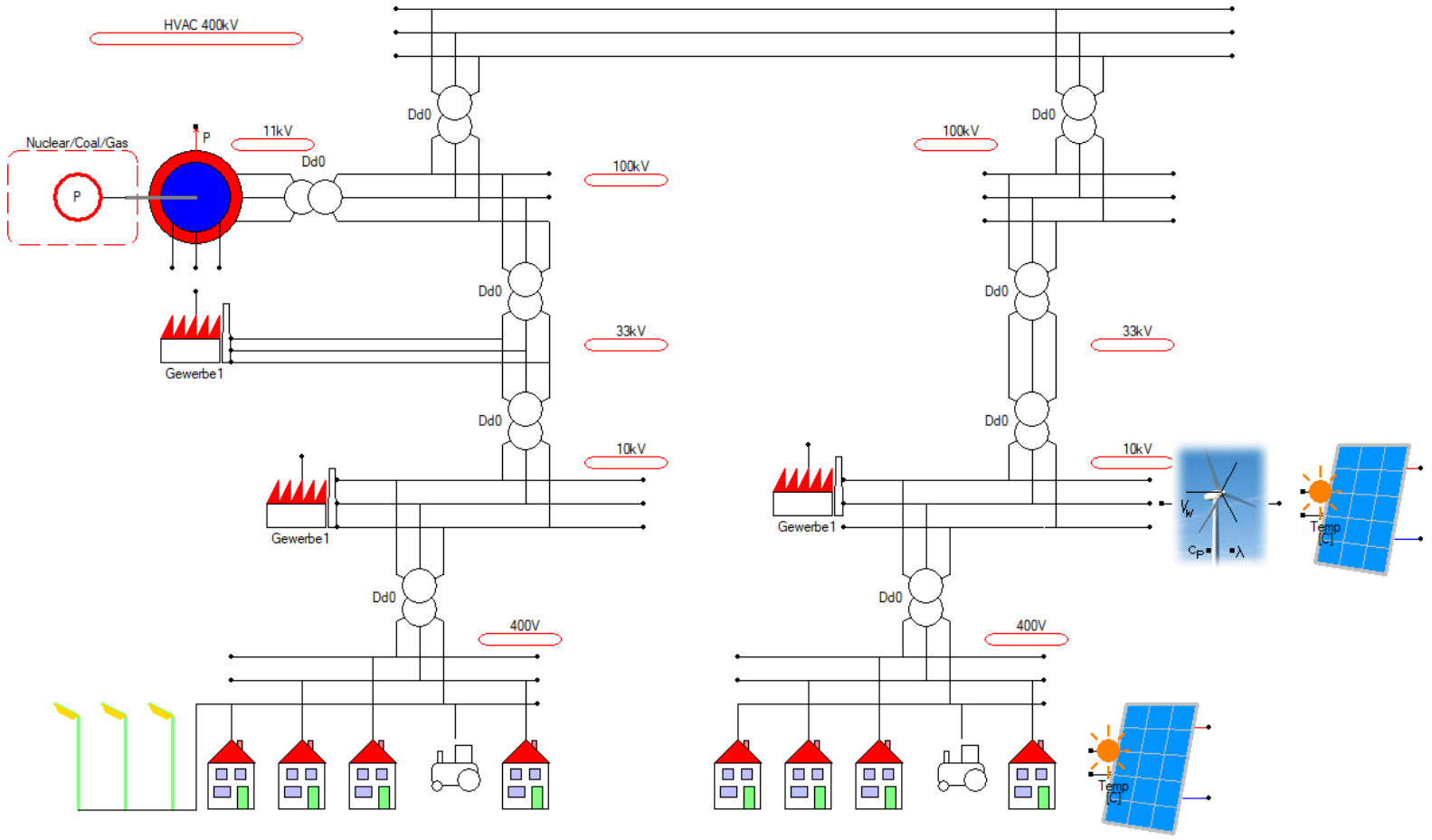
AC Grid Top-Down



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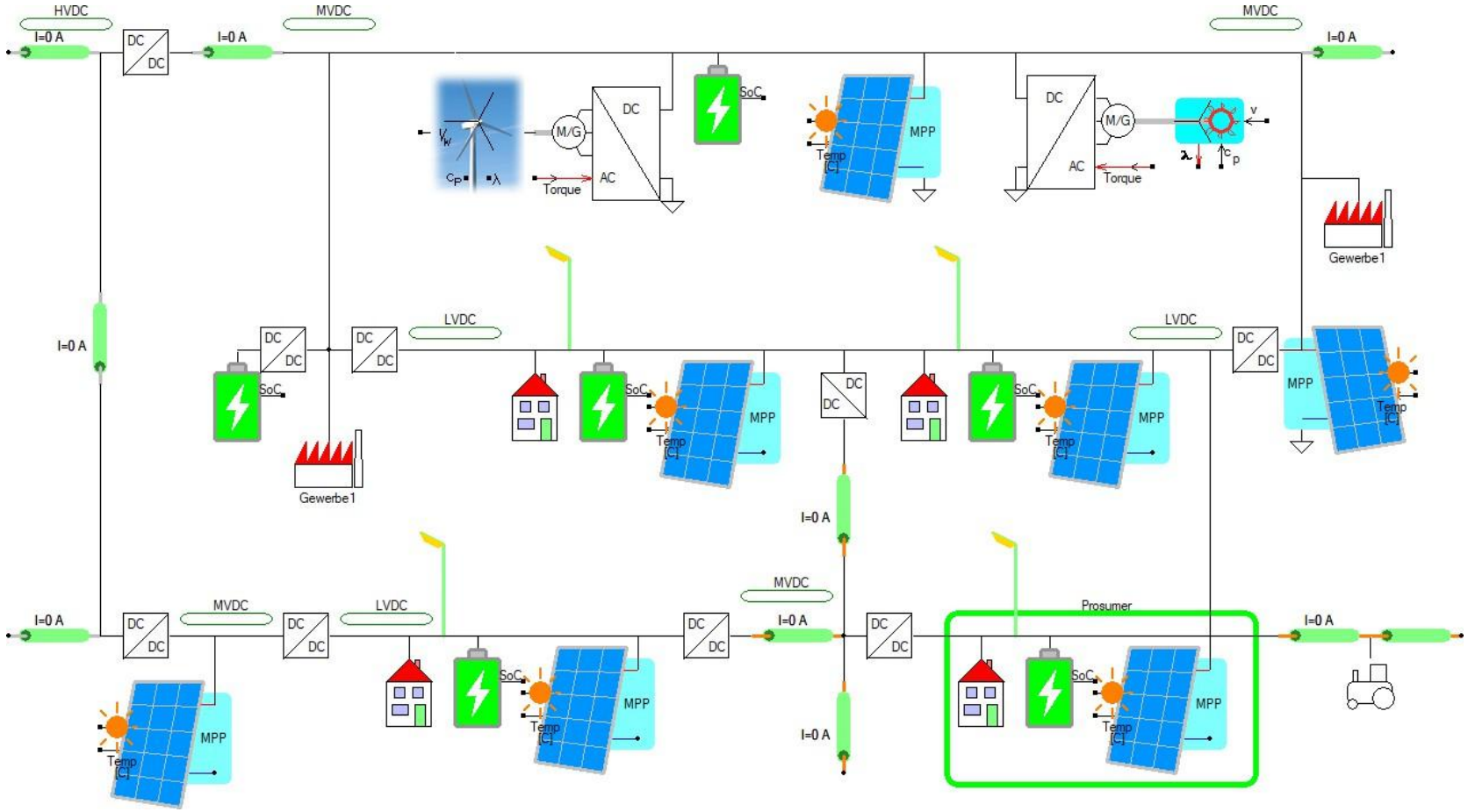
DC Grid Prosumers



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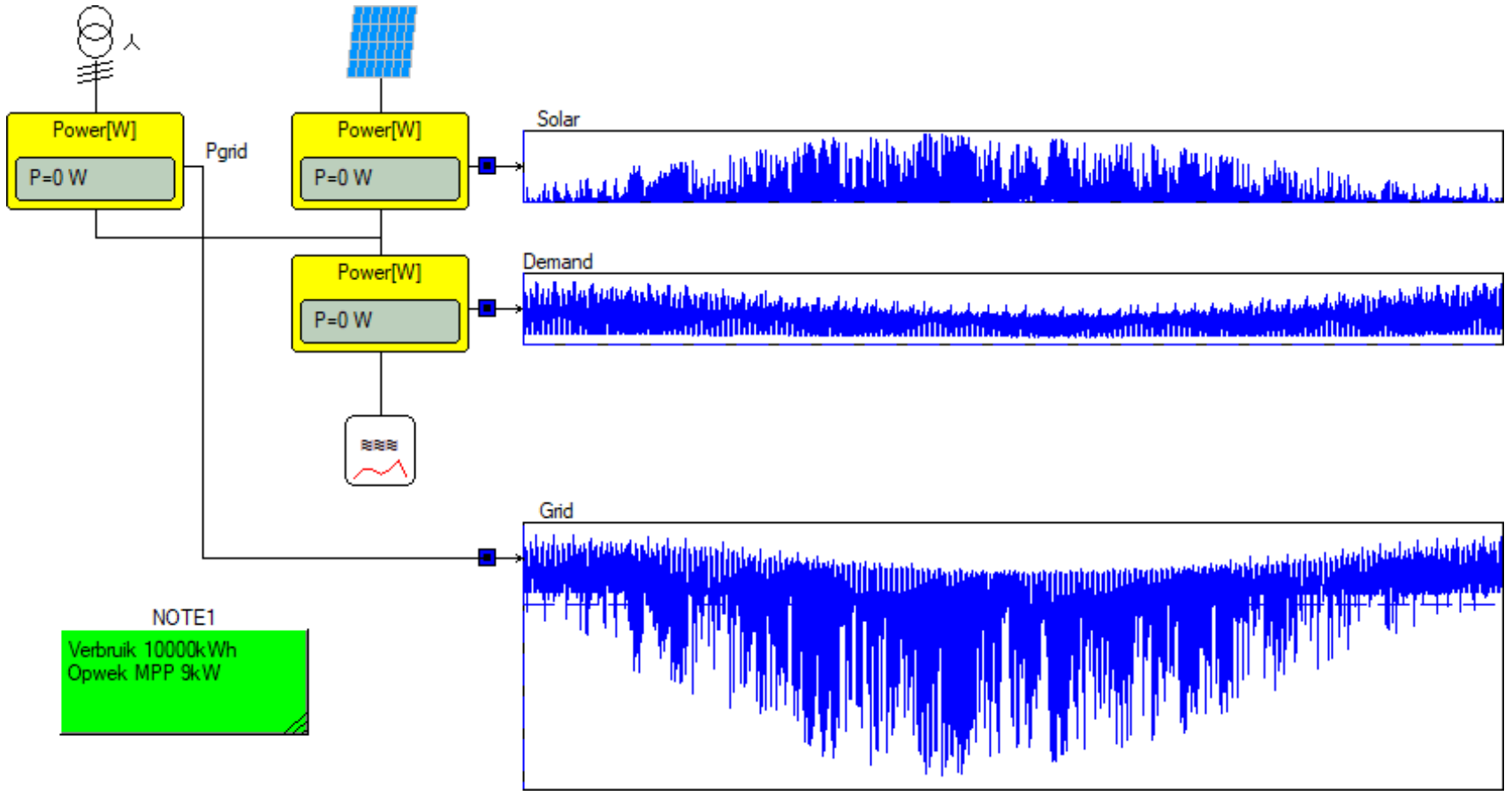
Power Usage, but how much and when?

- Huishouden
  - $1\phi - 3kW\,(3MWh/yr)...3\phi - 10kW\,(10MWh/yr)$
- Office
  - $1kW$ per employee
- Industry
  - $> 100kW$

Household: Solar 9kW, Load 10000kWh



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https://caspoc.com/tools/miscellaneous/simulator/

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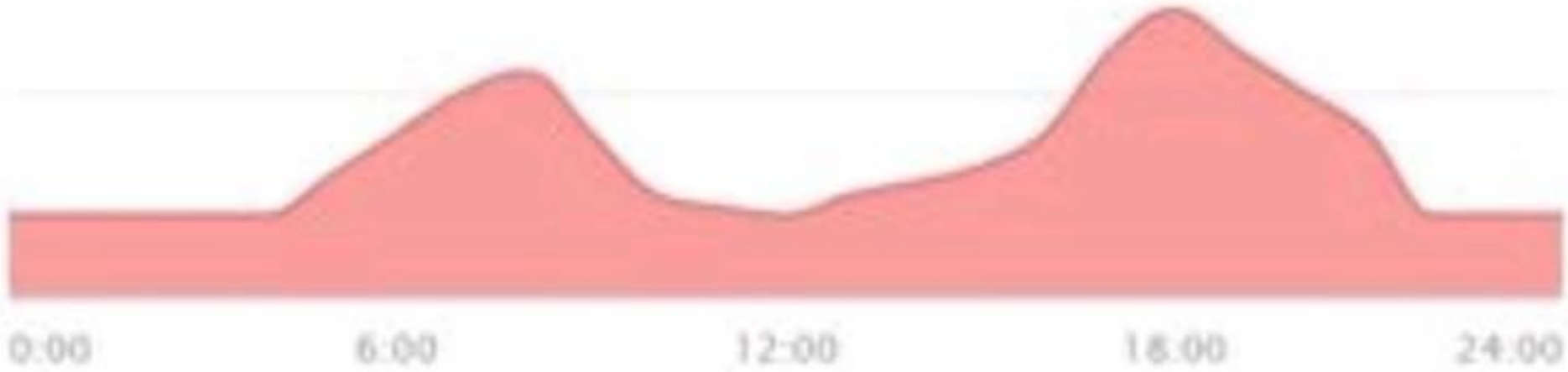
https://caspoc.com/tools/powerelectronics/acdc/gridtied/

https://caspoc.com/tools/powerelectronics/dcac/gridtied/

https://www.caspoc.com/tools/powerelectronics/dcac/pwm/

Huishouden: Gezin met schoolgaande kinderen



Schoolgaande kinderen

Huishouden: Gezin met Baby en kleuters

Familie baby’s + kleuters

Huishouden met 1 of 2 Personen

Huishouden 1 of 2 personen

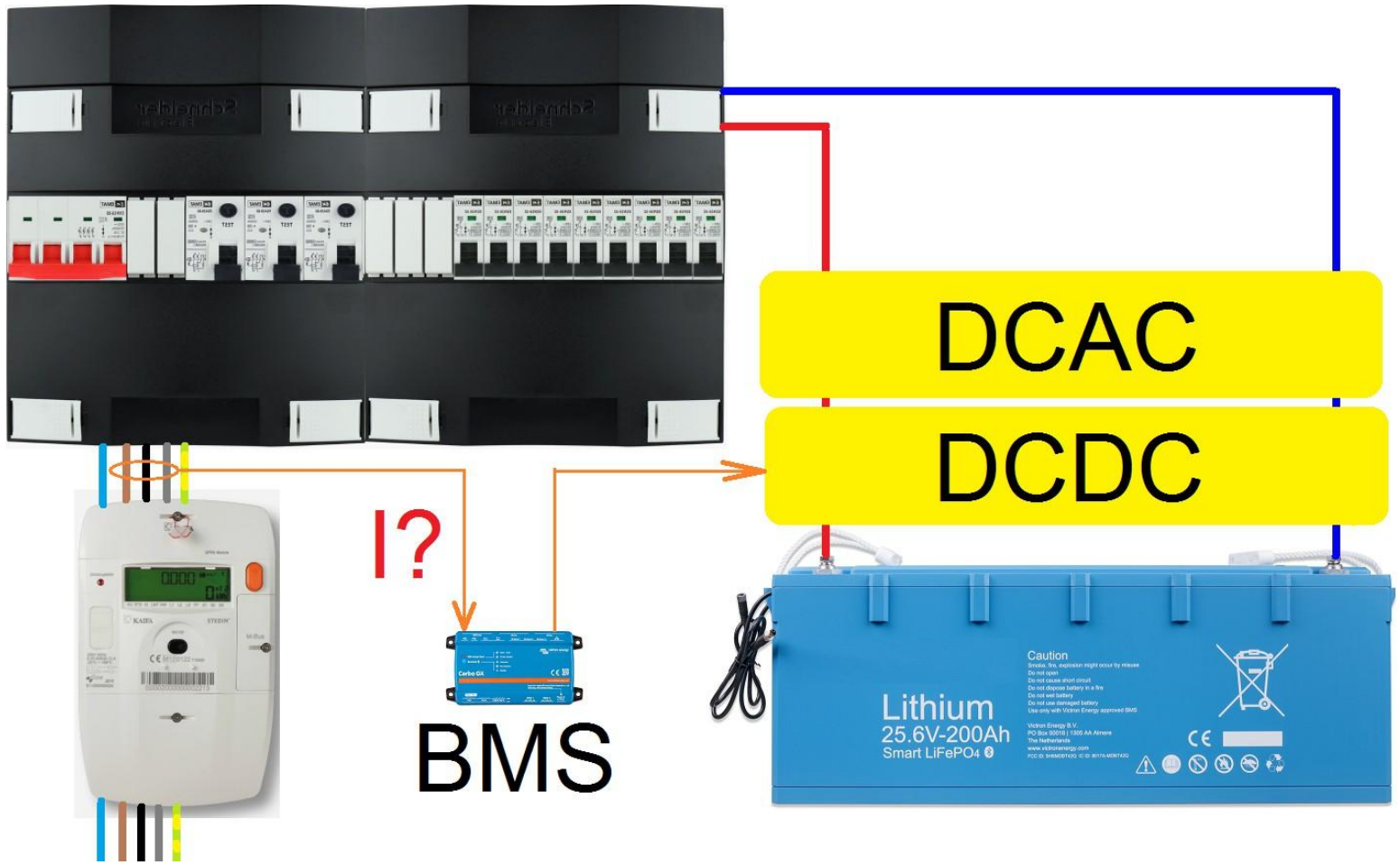
Huishouden: Gepensioneerd of Thuiswerkend

Gepensioneerd/thuiswerkend

Nachtgerichte Consumptie

Nachtgerichte consumptie

AC Grid with storage



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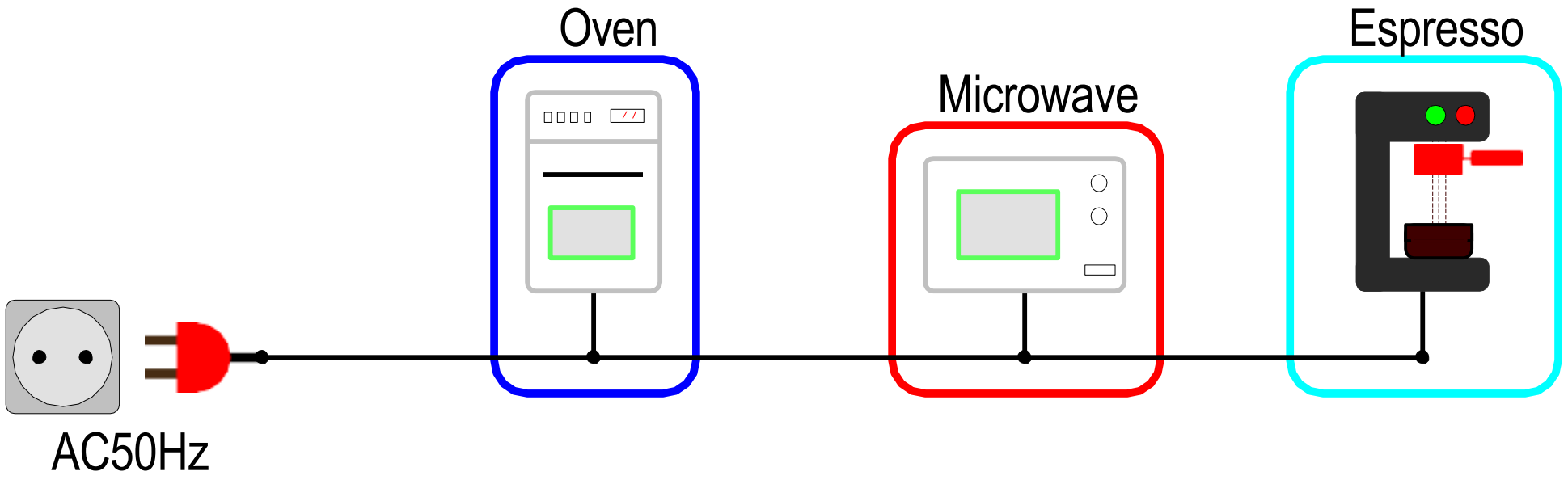
Kitchen



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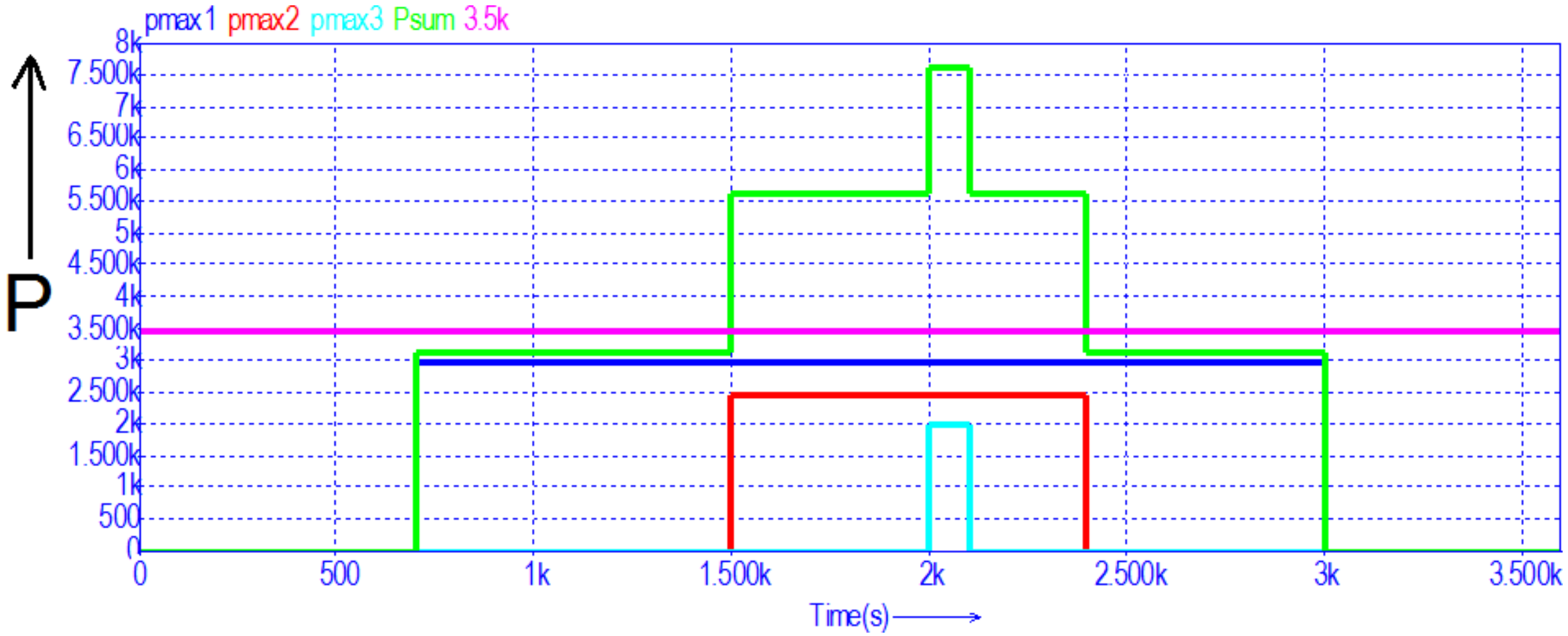
AC load for the kitchen



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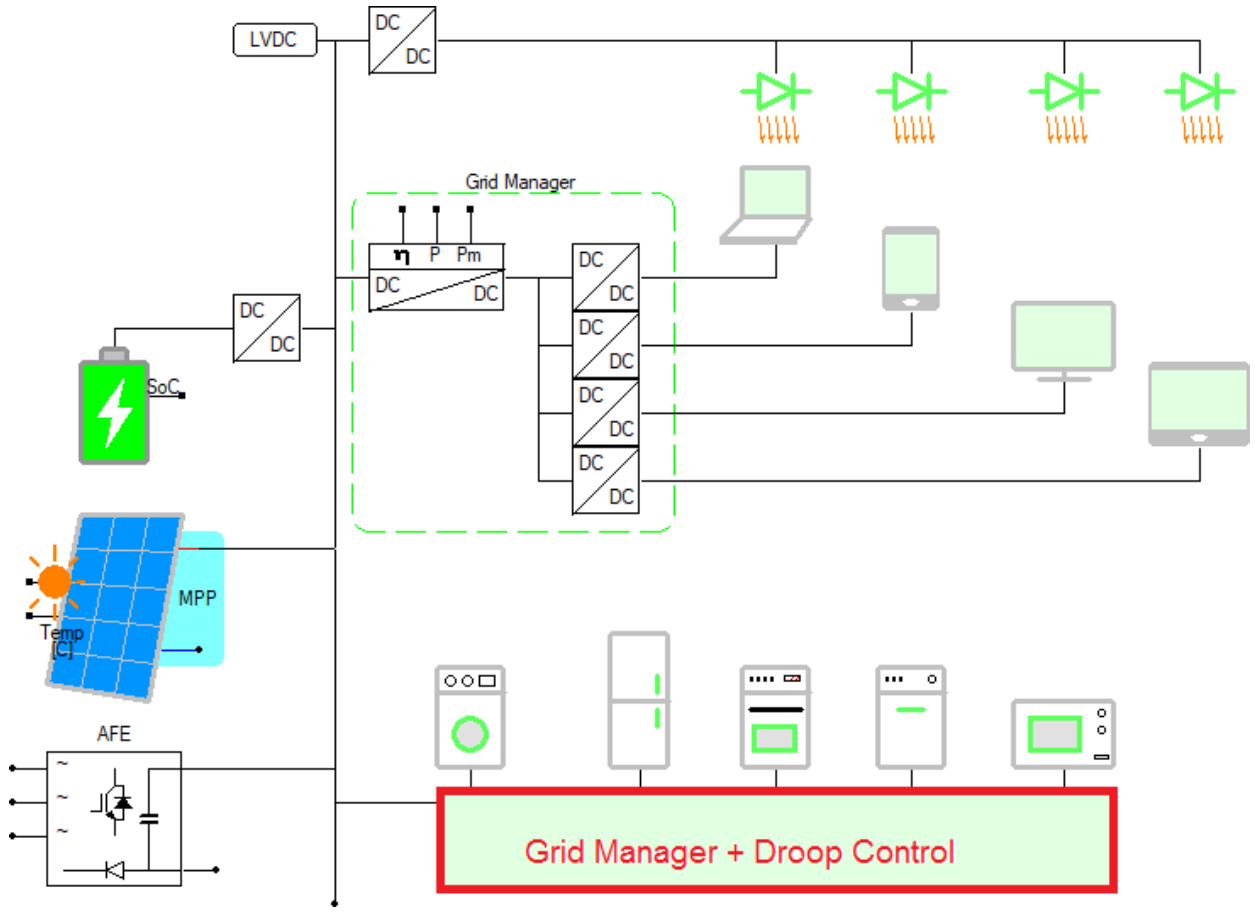
DC Grid Manager



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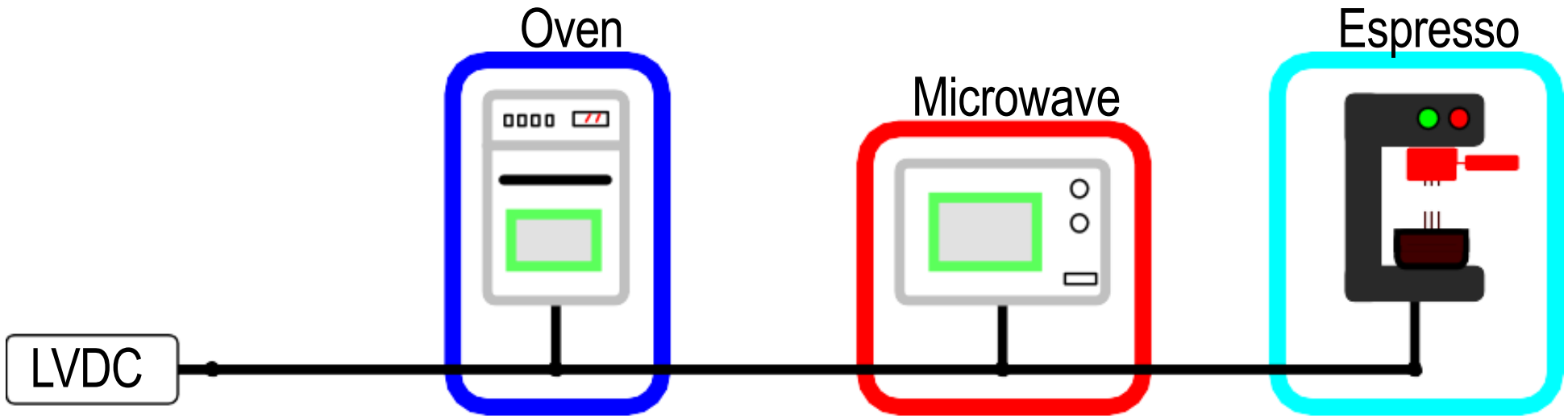
DC Kitchen



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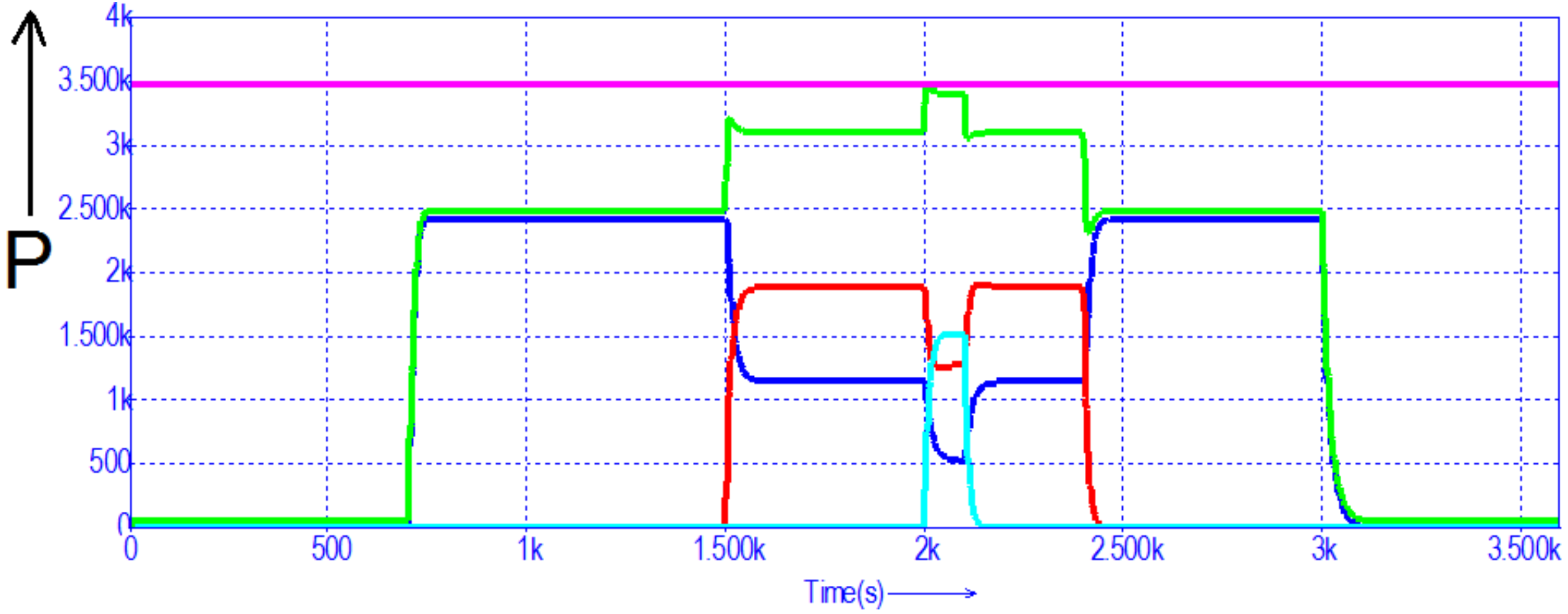
Usage with DC Droop Controlled Grid-Manager



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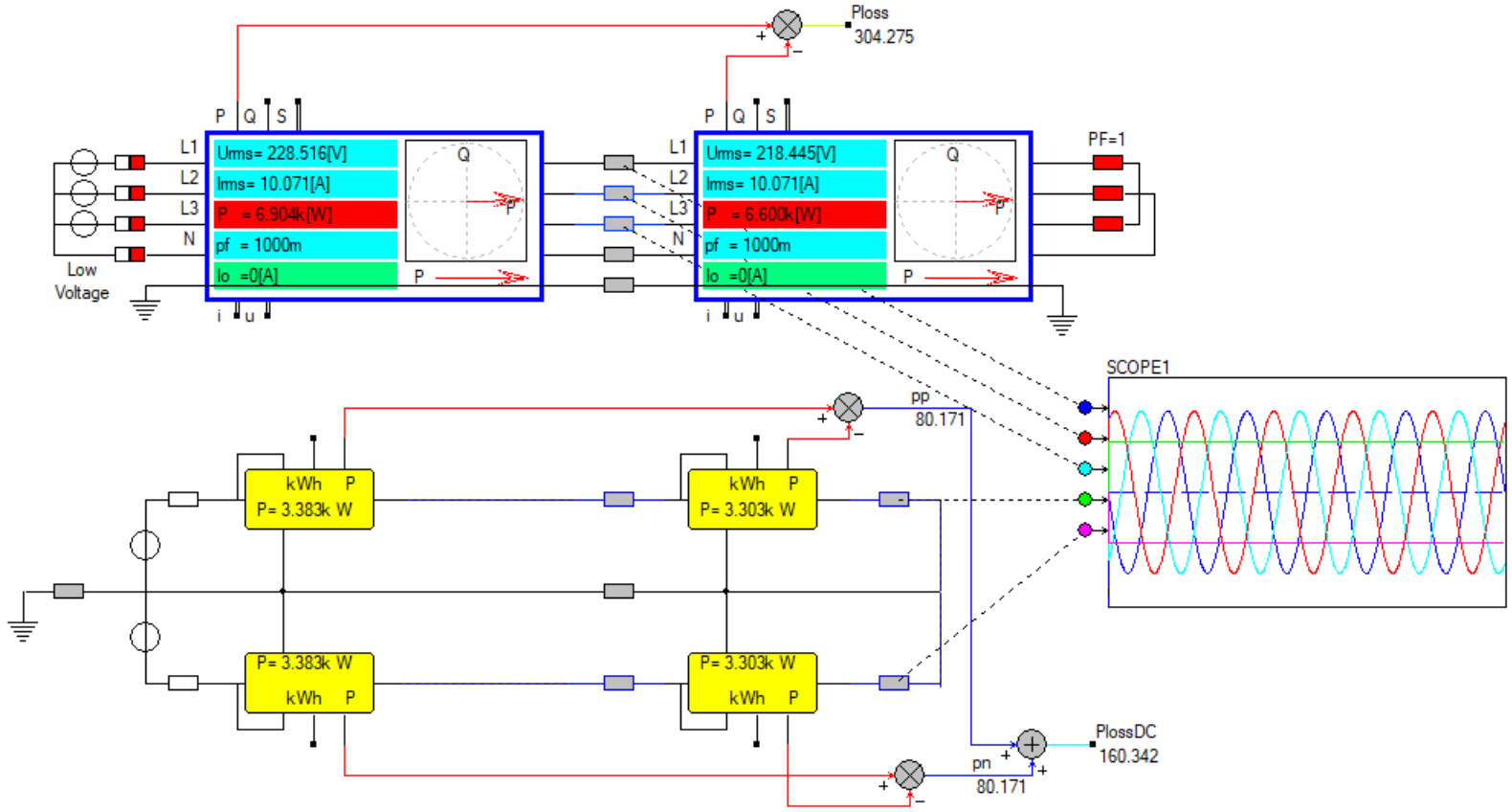
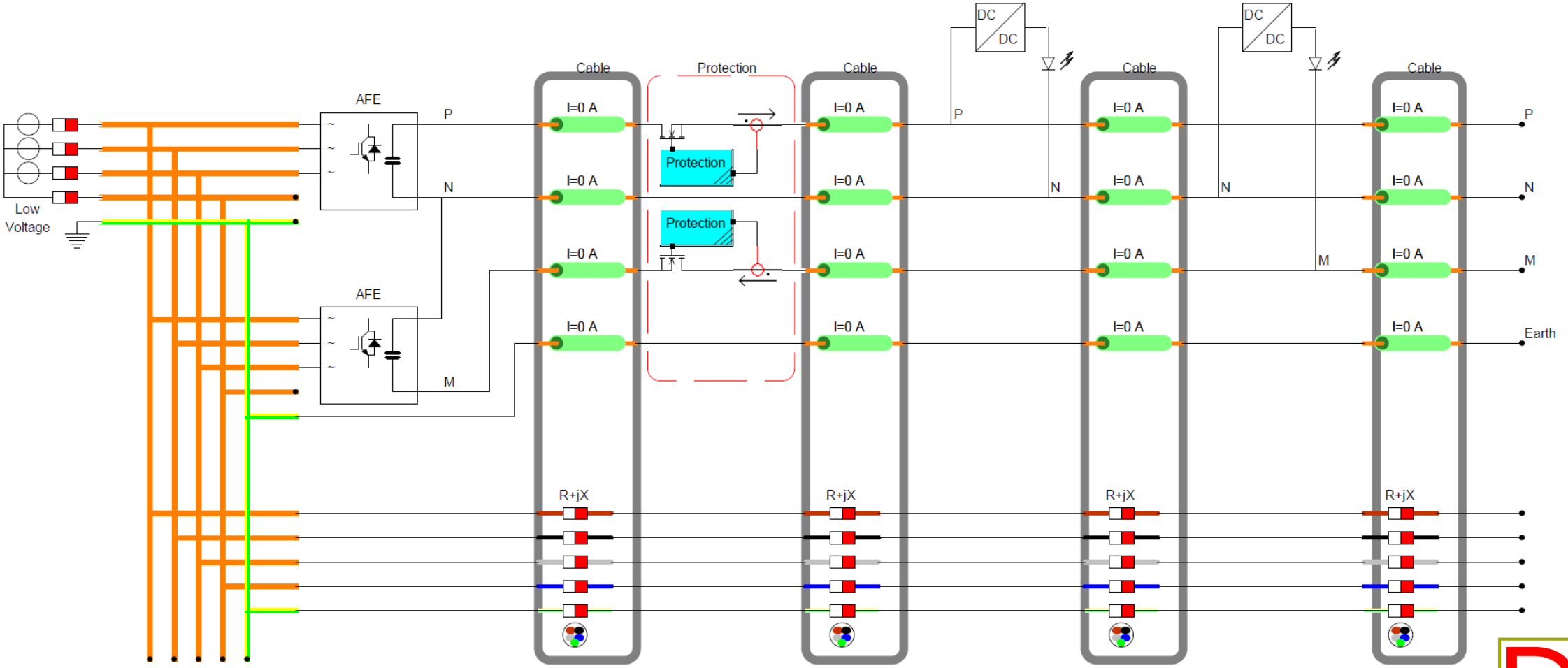
DC grid structure?

Structure of the DC Grid

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

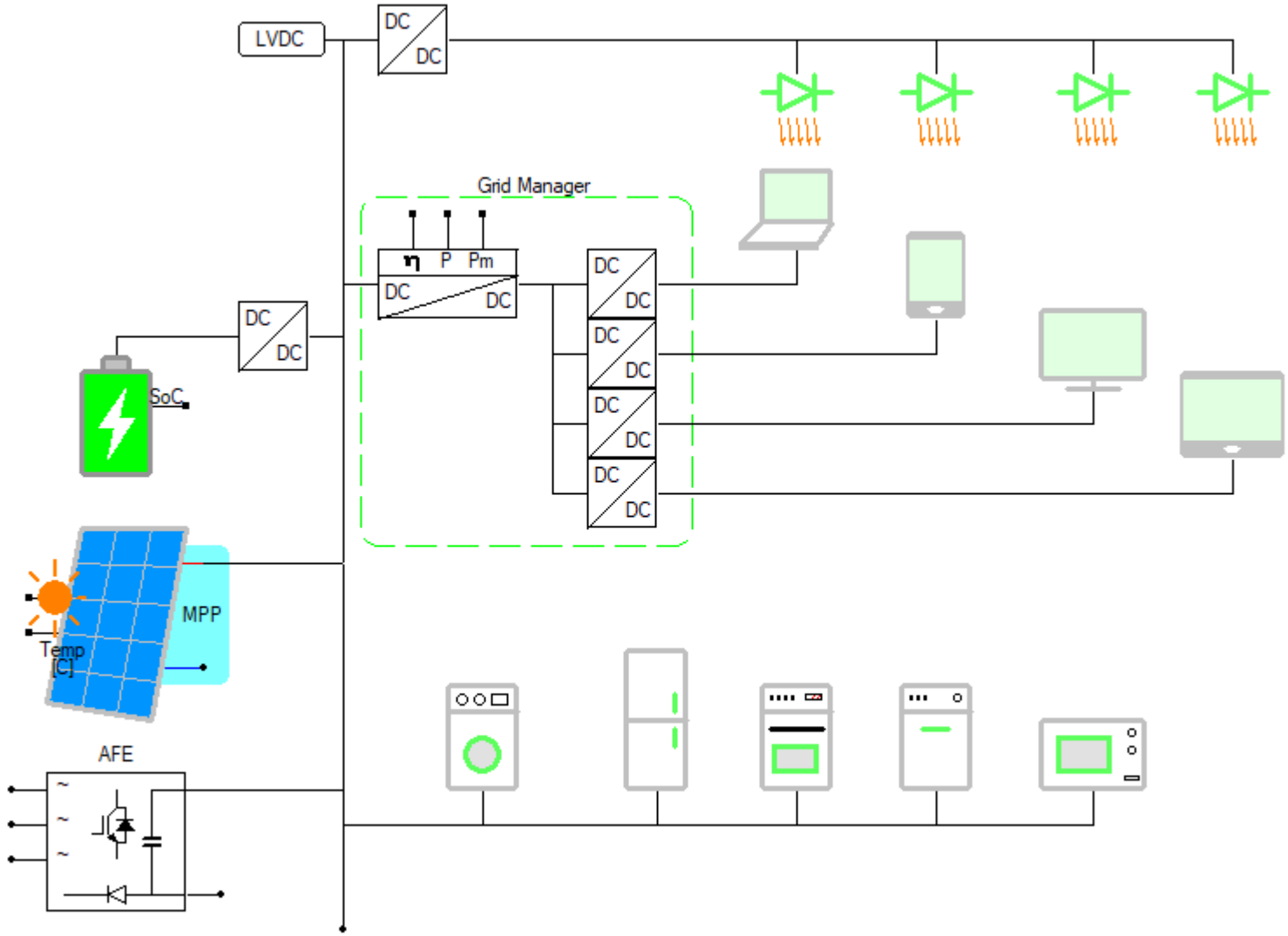


It is not about optimizing components
It is optimizing the system!



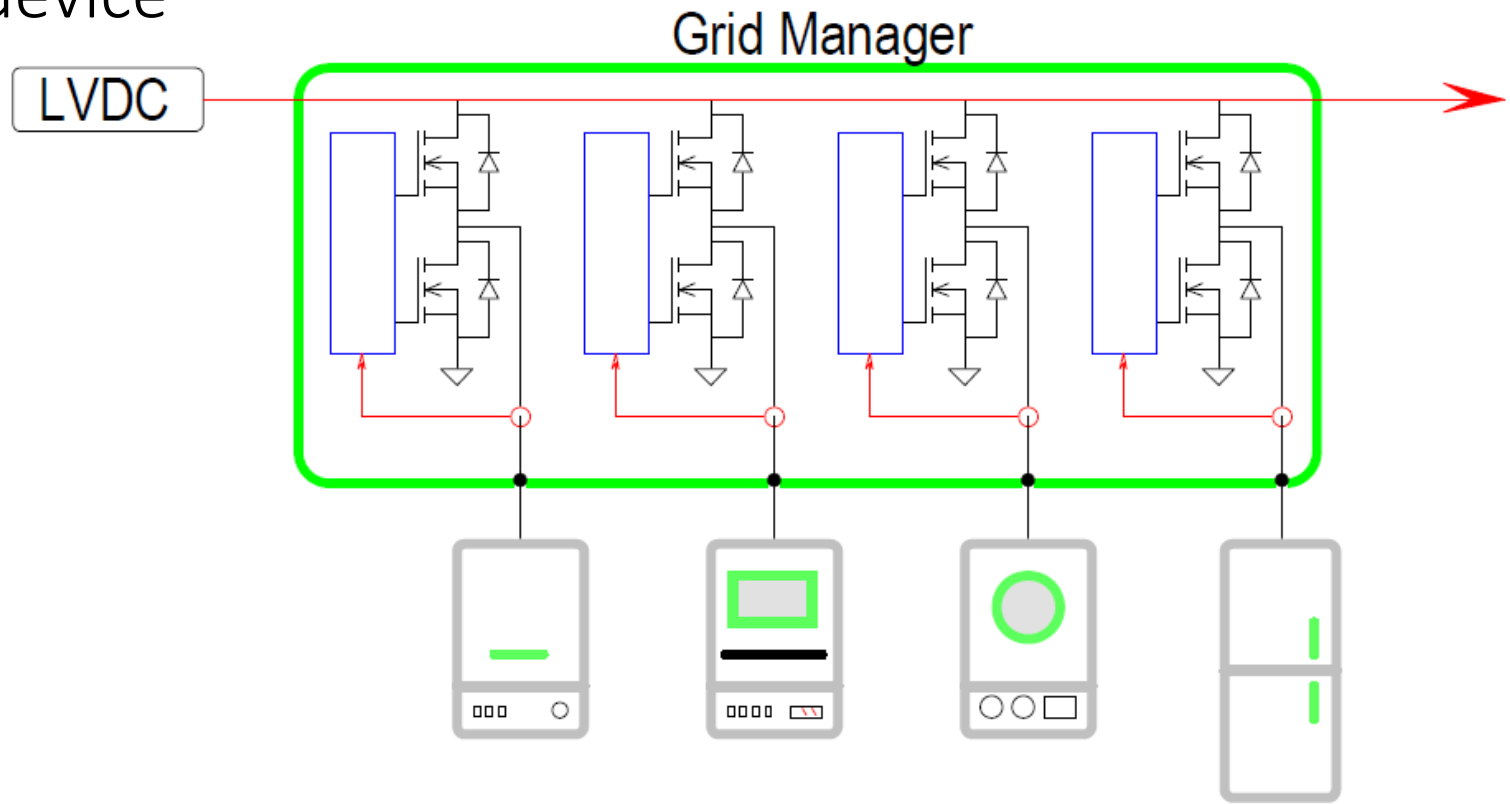
Which grid to choose?

- Centralized
- Decentralized



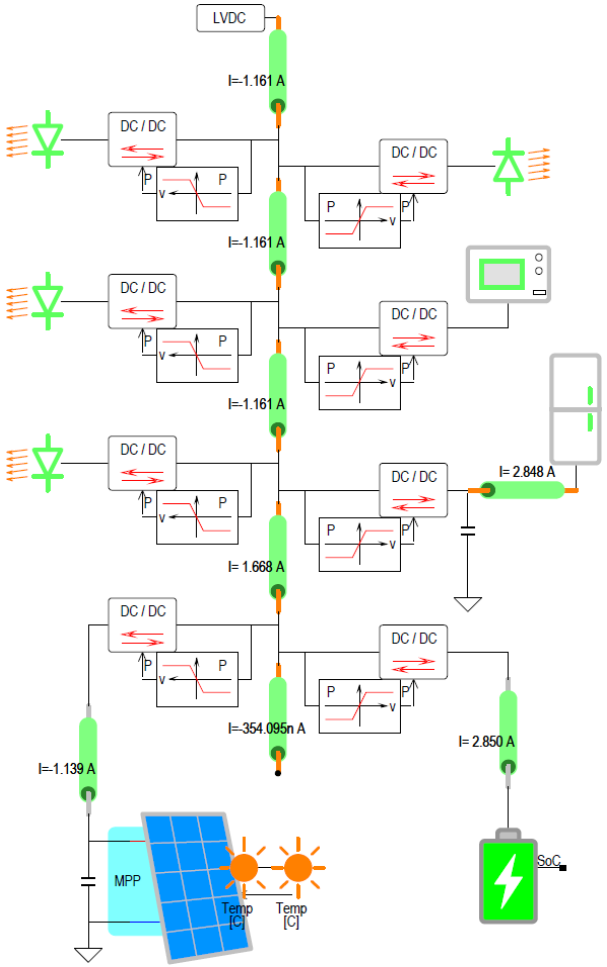
Centralized DC Grid with Grid Manager

- All control in one device
- Control of Power
- Breaker
- Inrush limiter

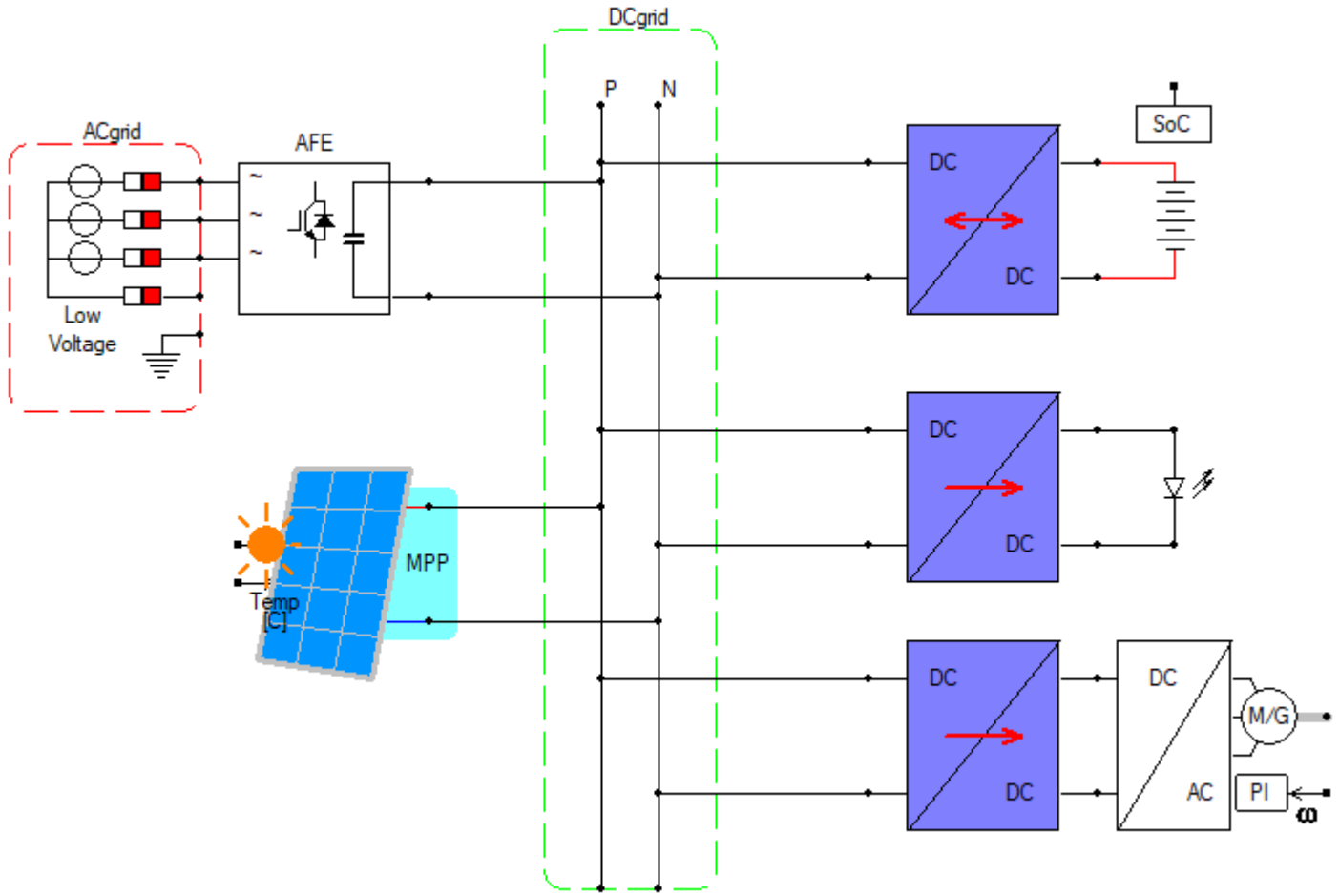


Decentralized DC Grid with Droop Control

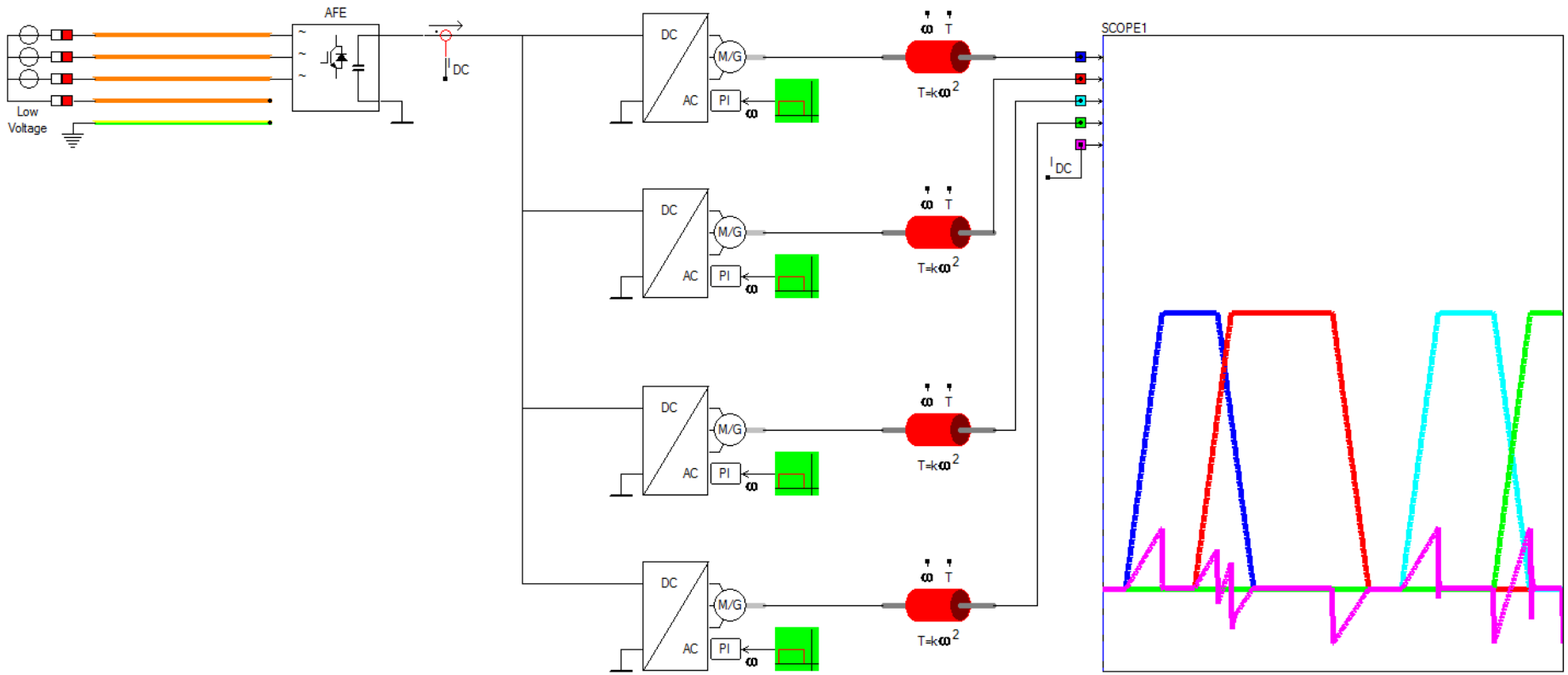
- Droop control per appliance
- DCDC converter per appliance



Producers and Consumers are directly coupled



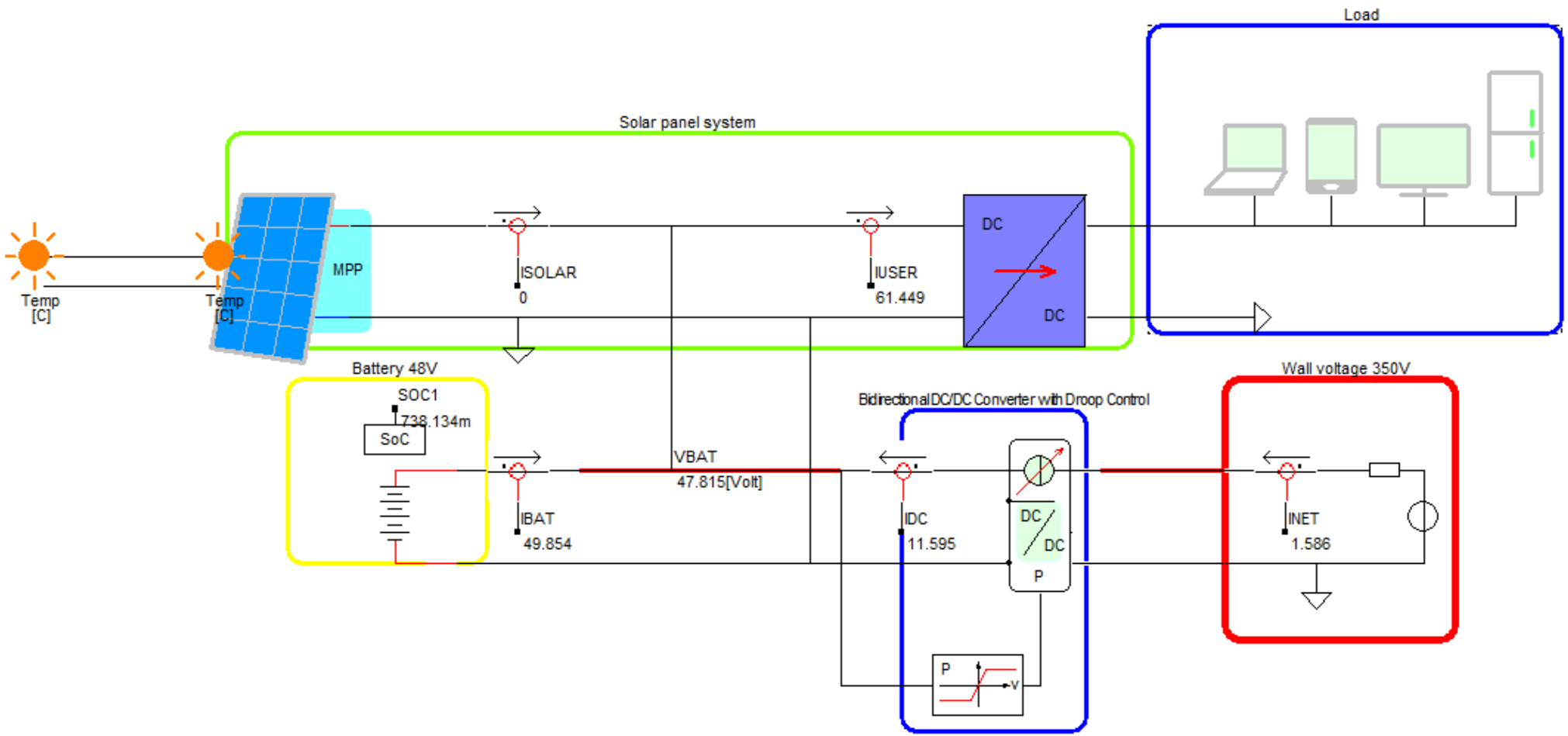
Exchange of Drive and Brake Energy



Ships connected to the DC grid

DC

DC Droop control per ship

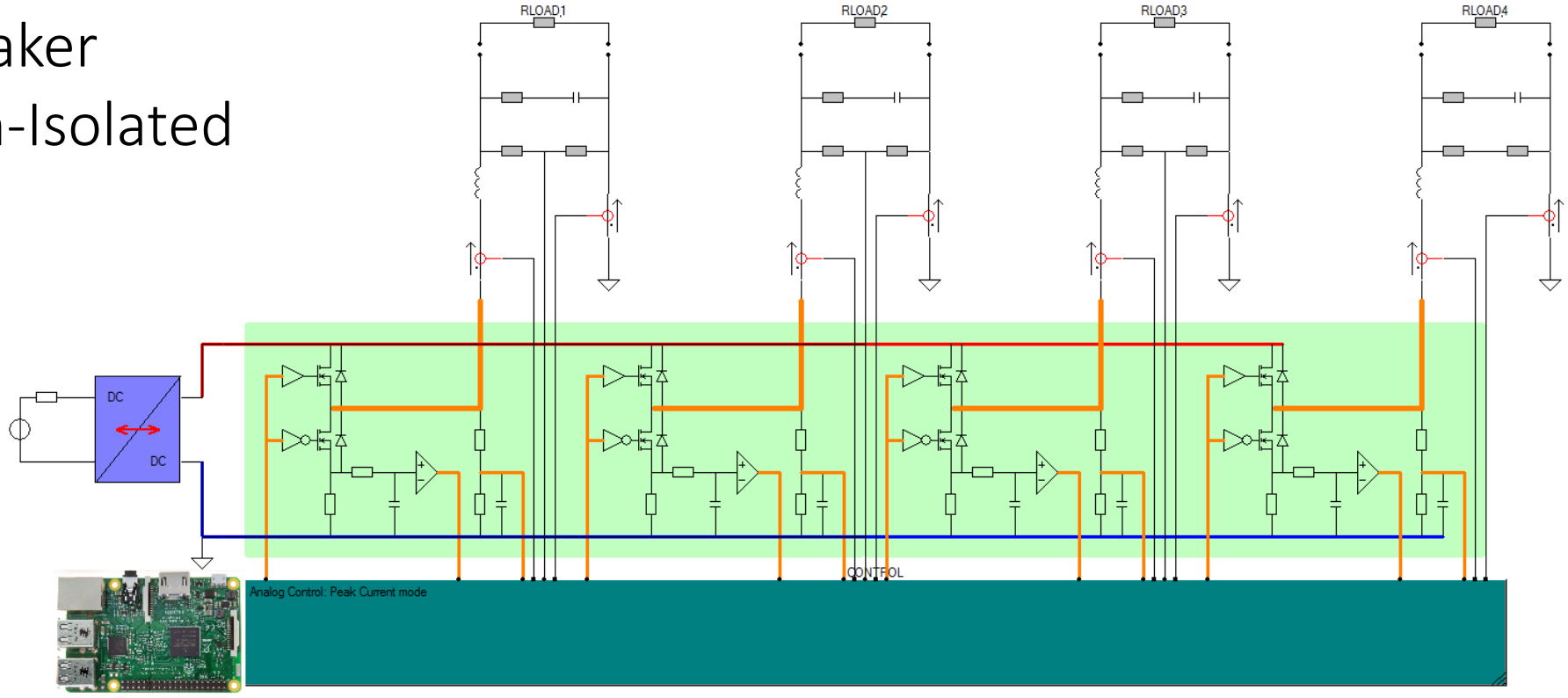


Switching in the DC grid?

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

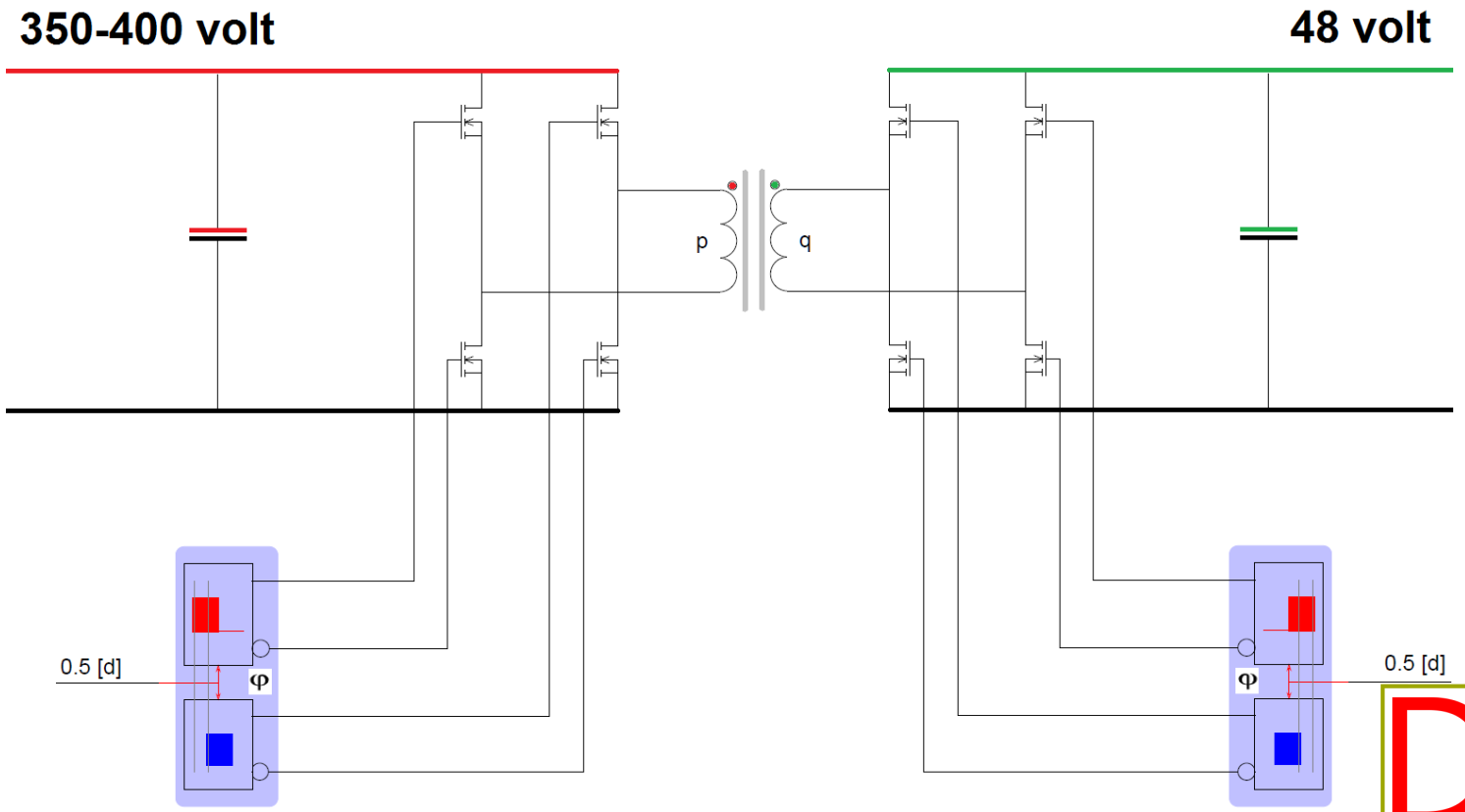
Grid Manager contains multiple Synchronous Buck Converters

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

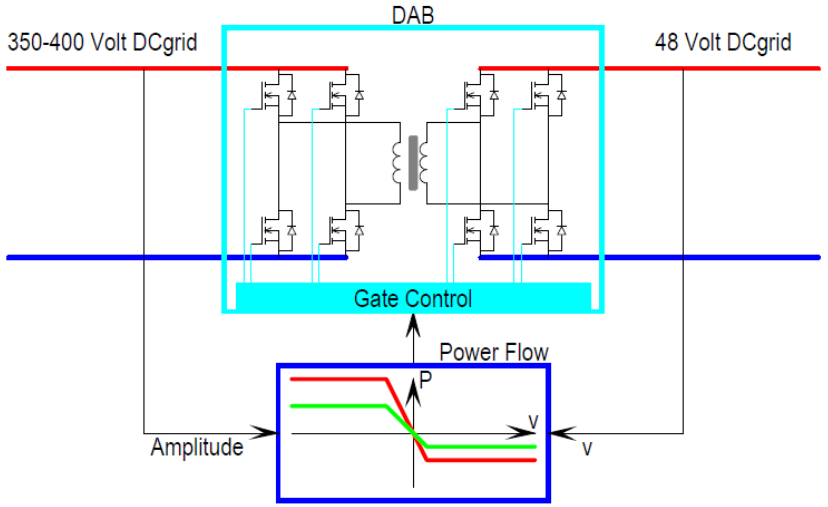


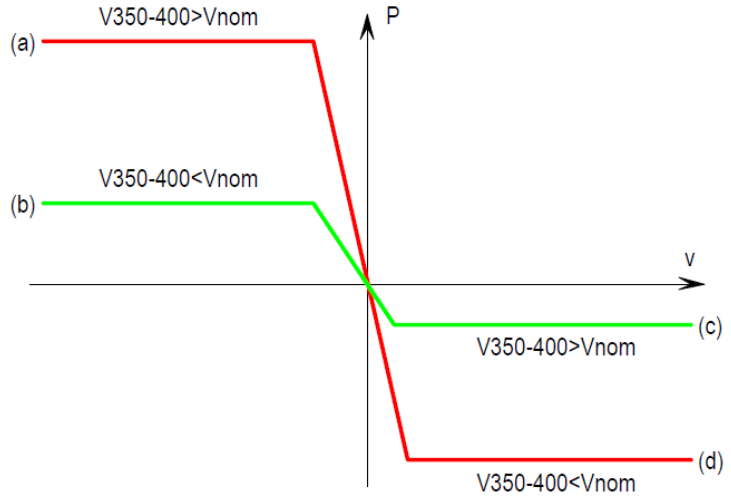
Dual Active Bridge is Isolated

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



Connecting two DC grids with different voltage levels



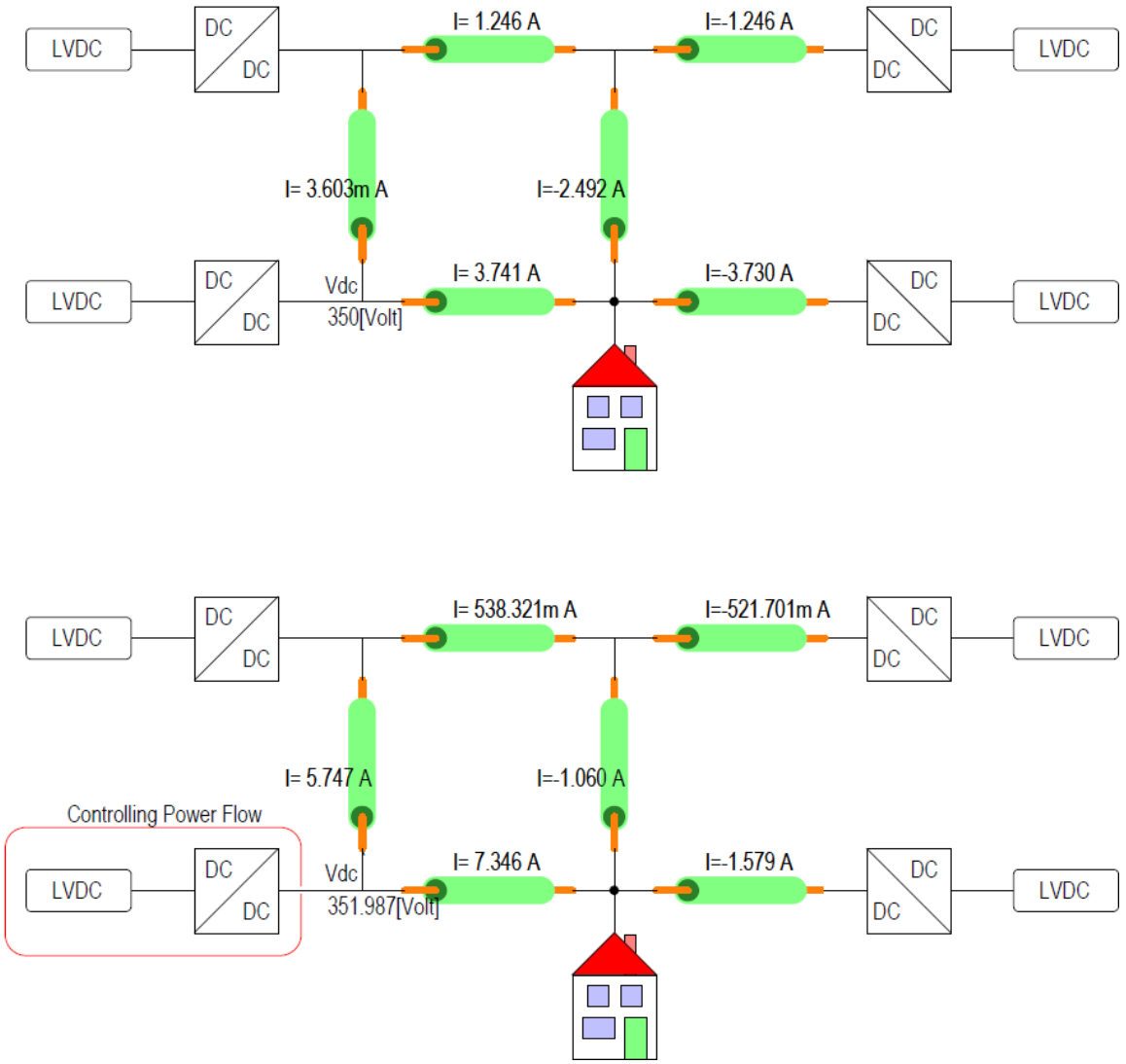


DC grid control?

Control and Power Congestion Management in the DC Grid

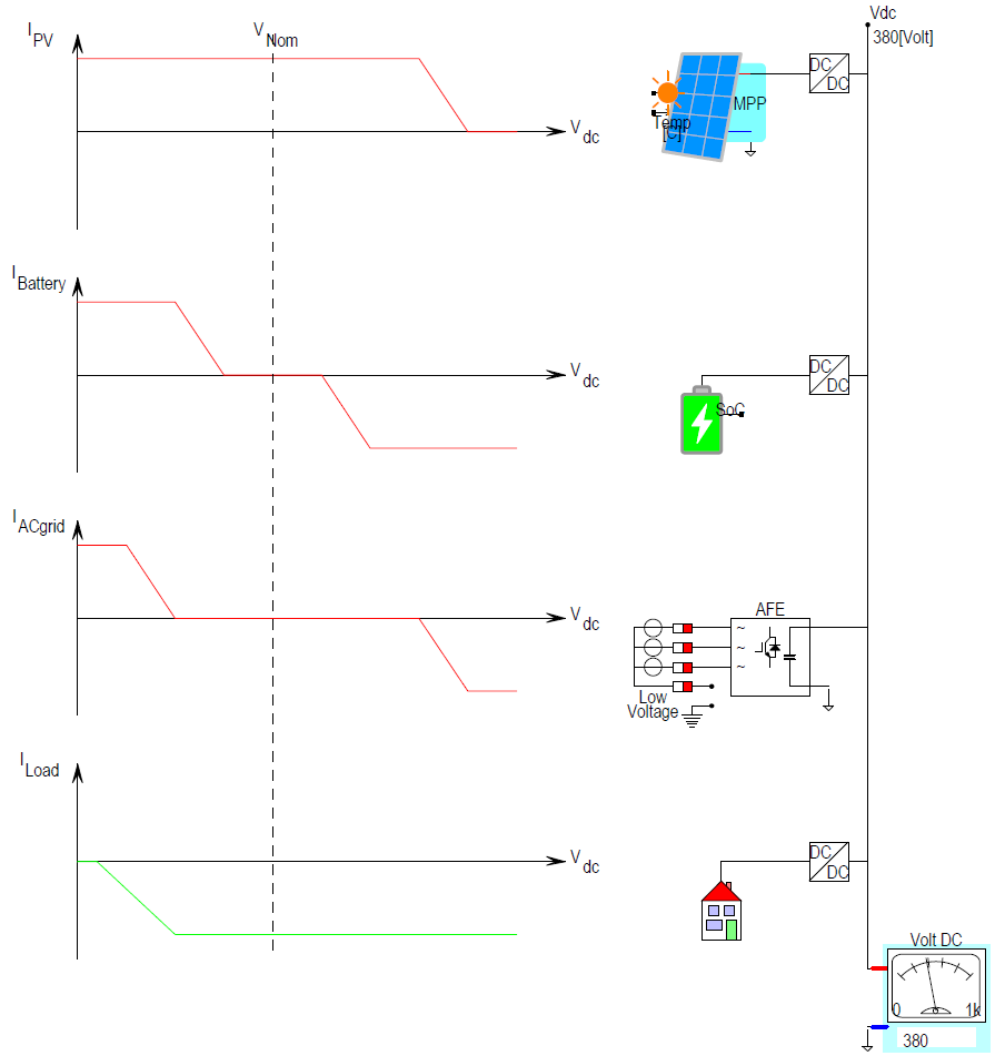
Control the current in a Meshed grid

- Nodal voltage defines current flow
- DCDC converters have losses



Droop Control regulates in a decentralized grid

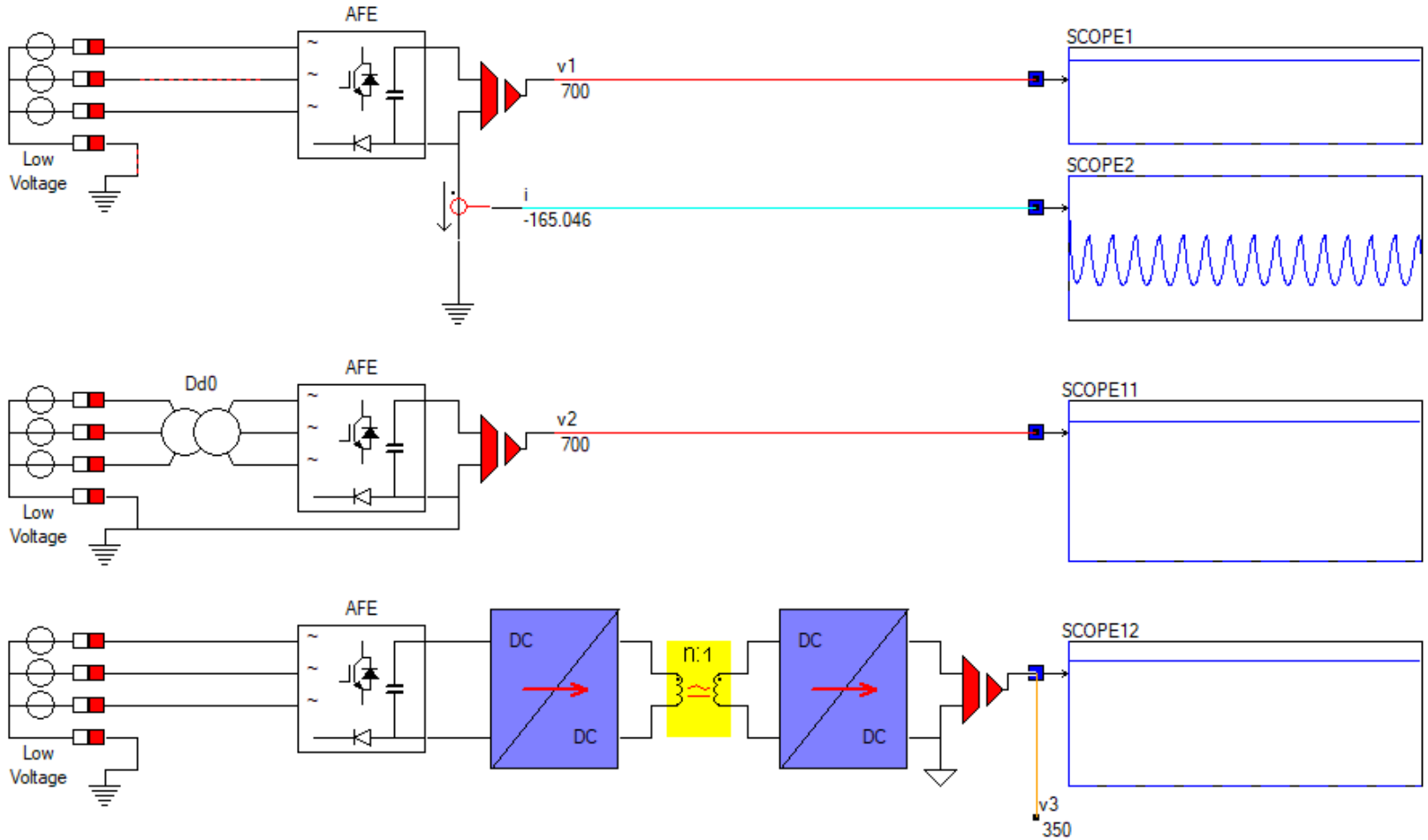
- Controlled current flow per appliance
- Islanding operation
- No communication required



DC grid selectrivity and protection?

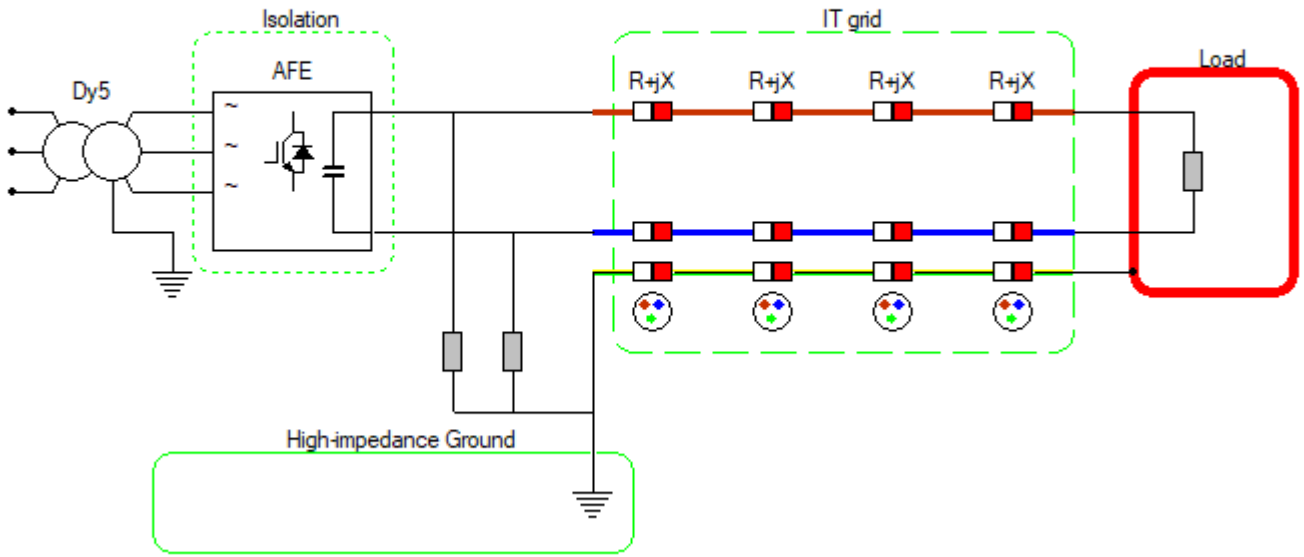
Protection and/or selectivity
in the DC Grid?

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

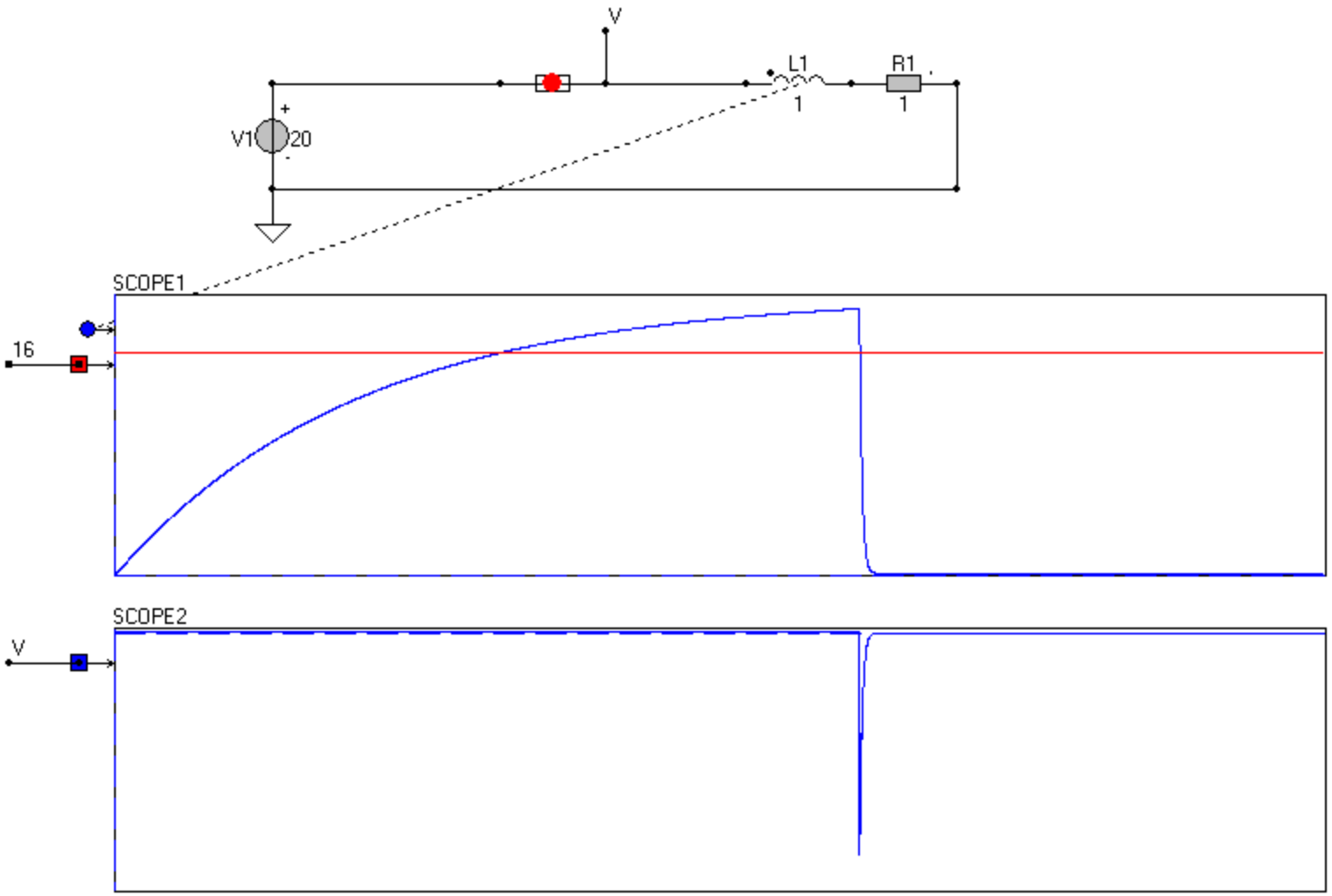


Grid system?

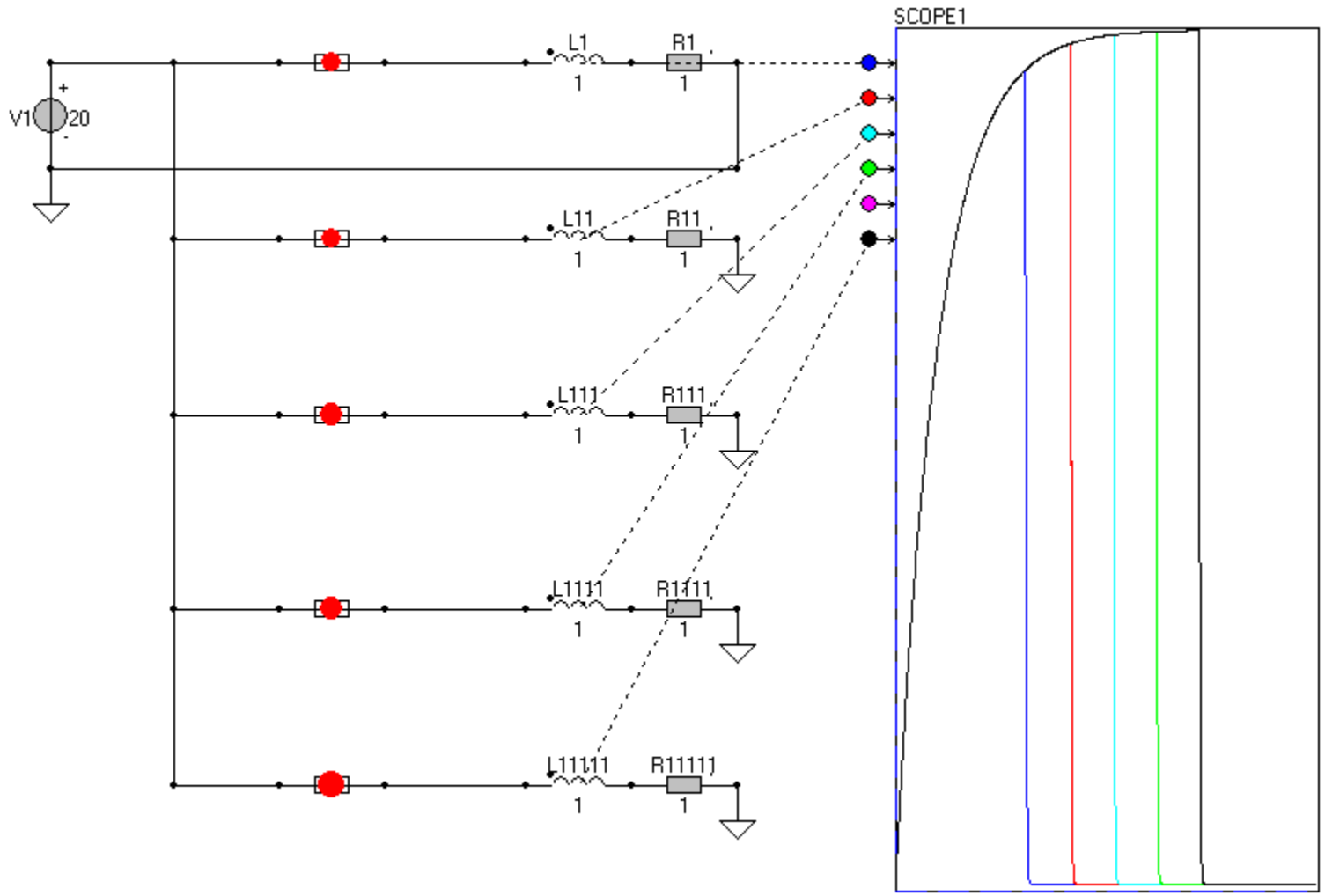
- You can choose an isolated Grid IT to implement earth leakage detection,
- but your grid is floating!



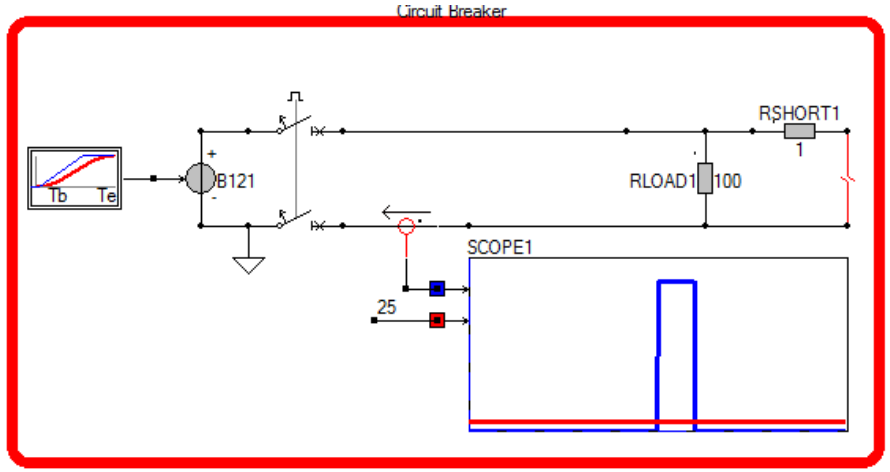
Fuse?

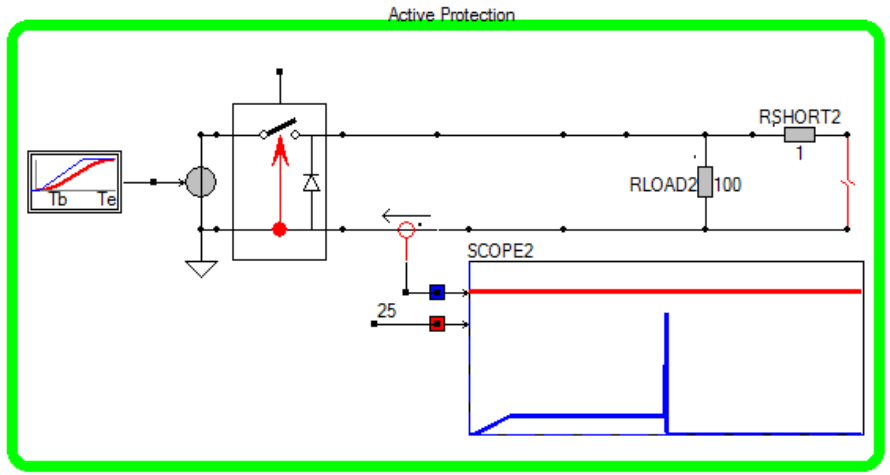


Fuse?


V1
20
L1
1
R1
1
L11
1
R11
1
L111
1
R111
1
L1111
1
R1111
1
L11111
1
R11111
1
SCOPE1

RoCoC Rate of Change of Current



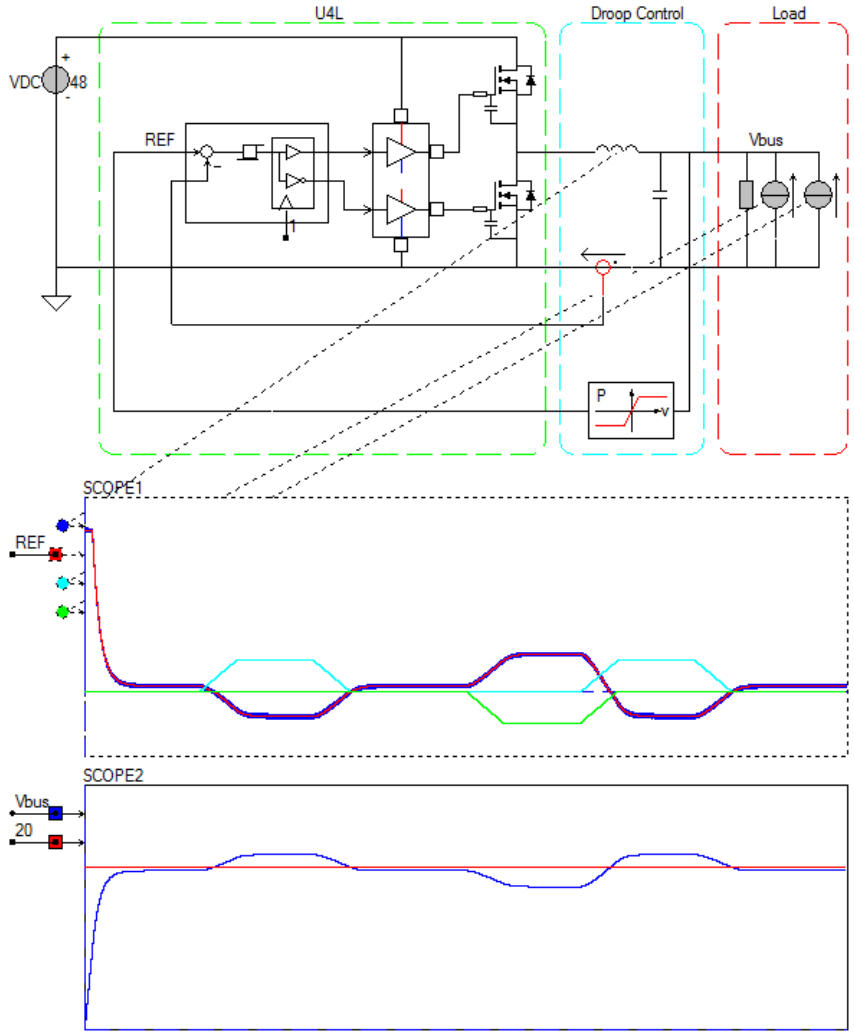


DC grid stability?

How to predict and ensure stability in the DC Grid

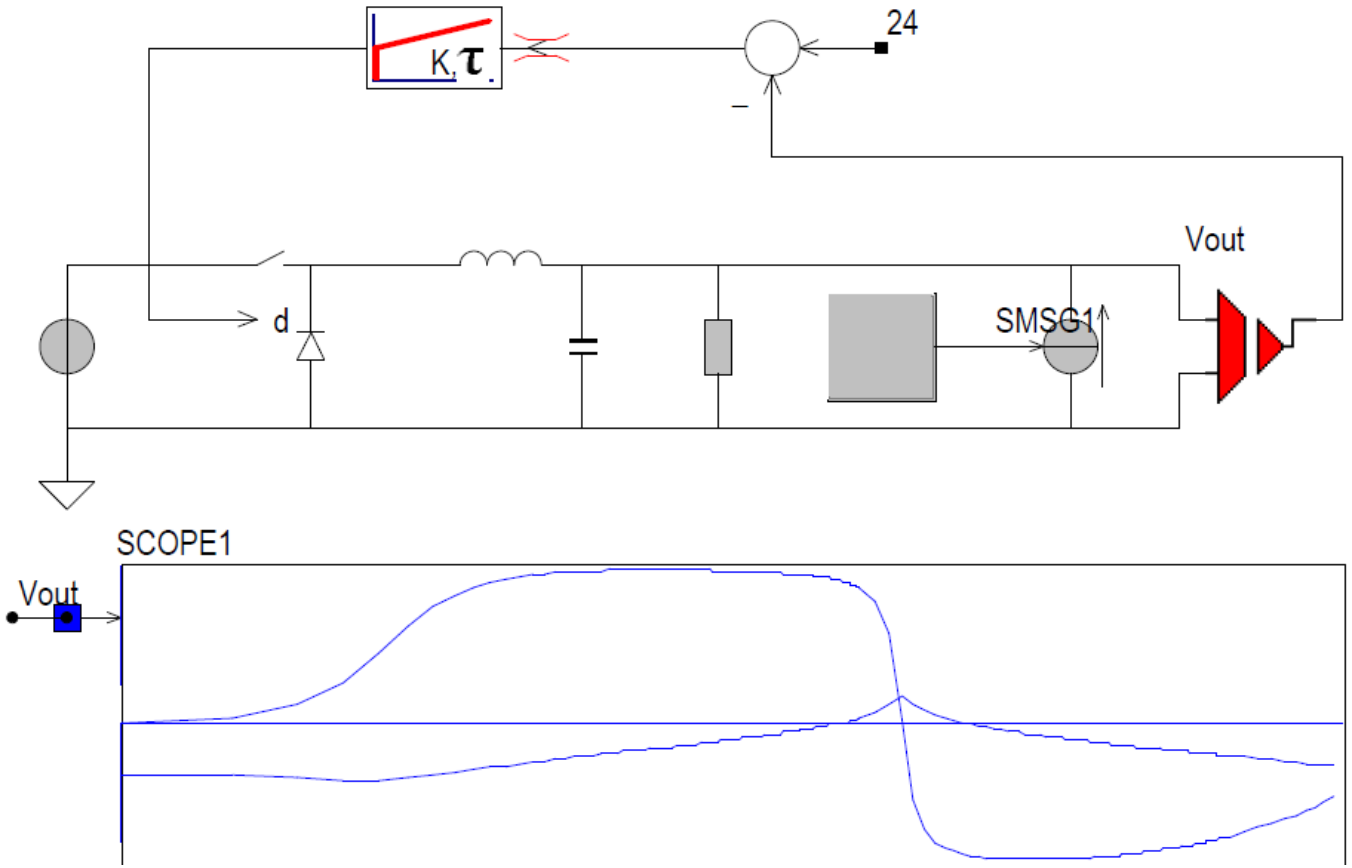
Static stability depends in Droop Control Characteristics

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



Dynamic stability depends on input and output impedance

- Zout < Zin
- Middlebrooks Stability Criterion



Conclusion: Power Electronics!

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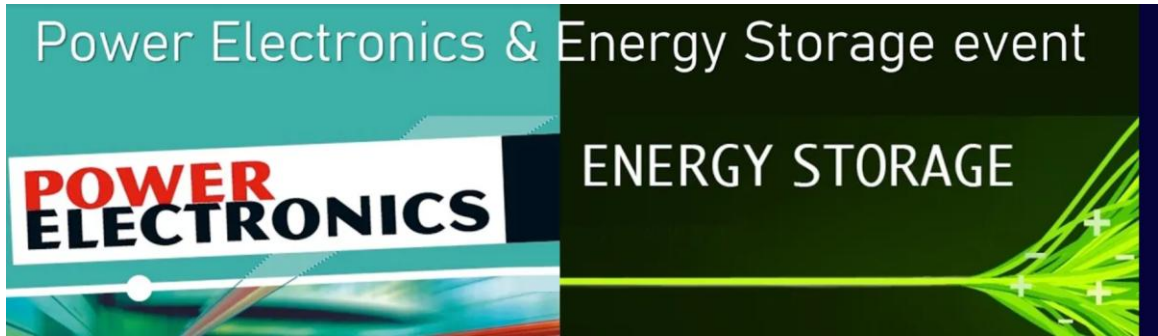
Thanks for your attention!

www.dc-lab.org



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