

DC grids for marine charging and electric propulsion

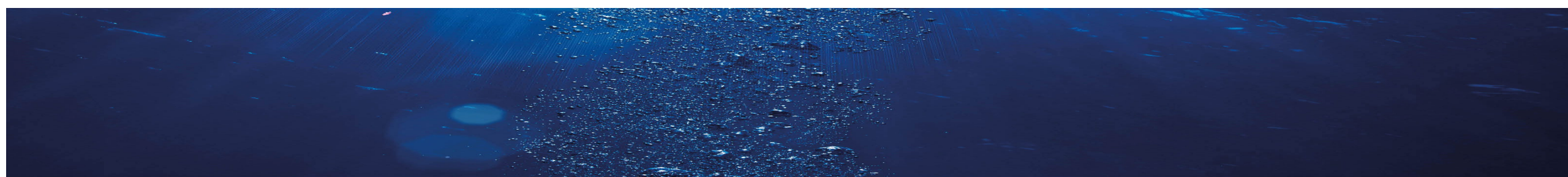
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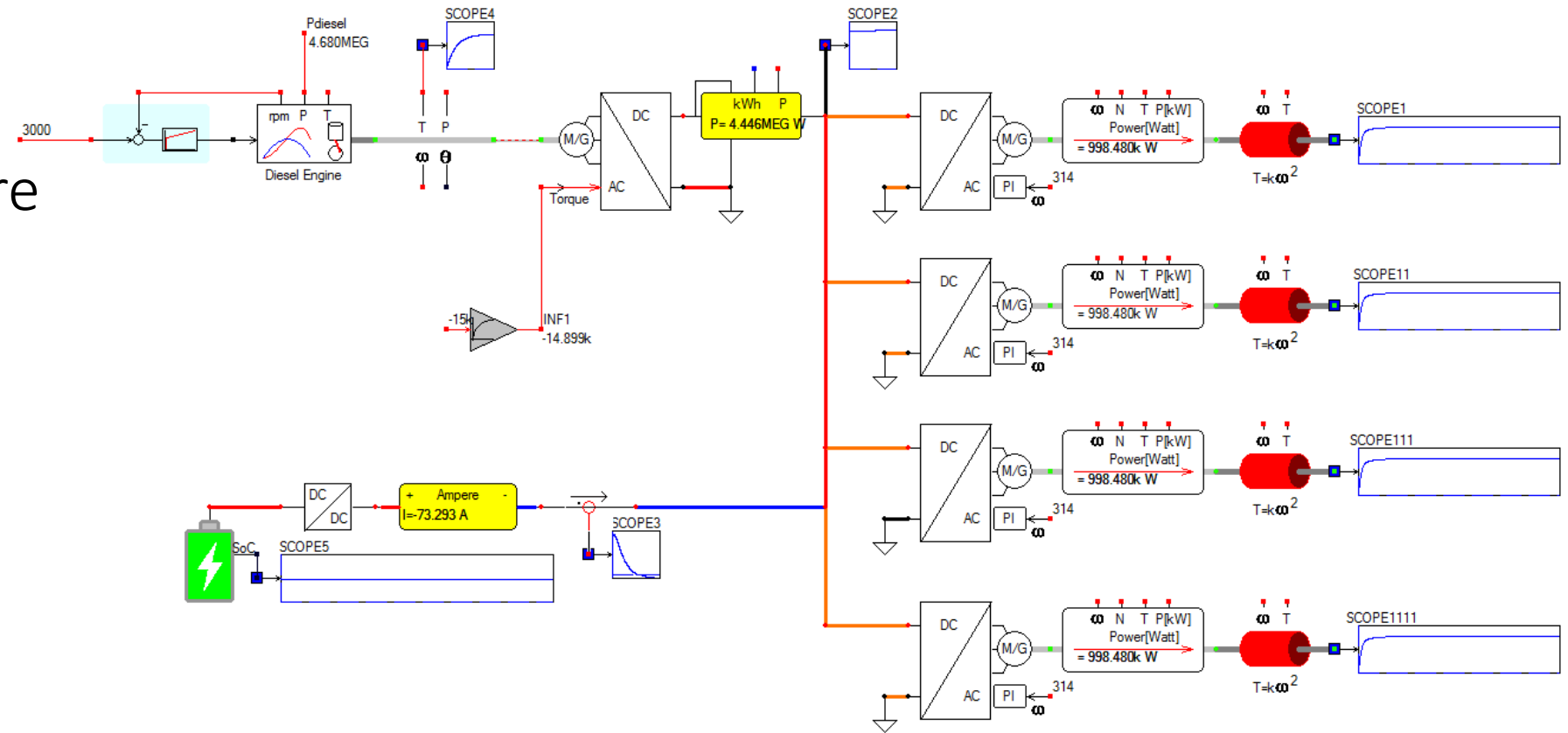


CaspoC



Contents

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

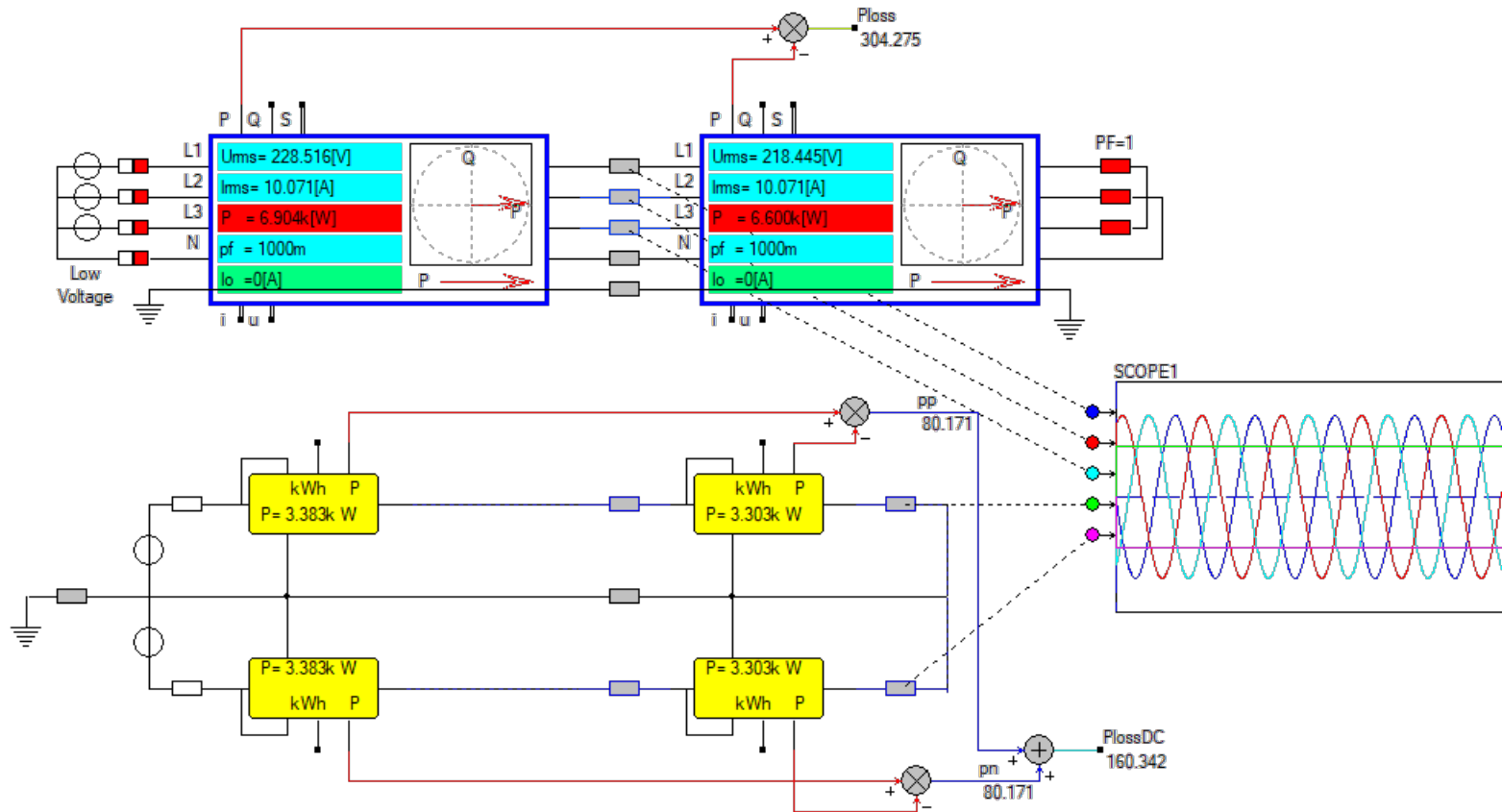


DC grid structure?

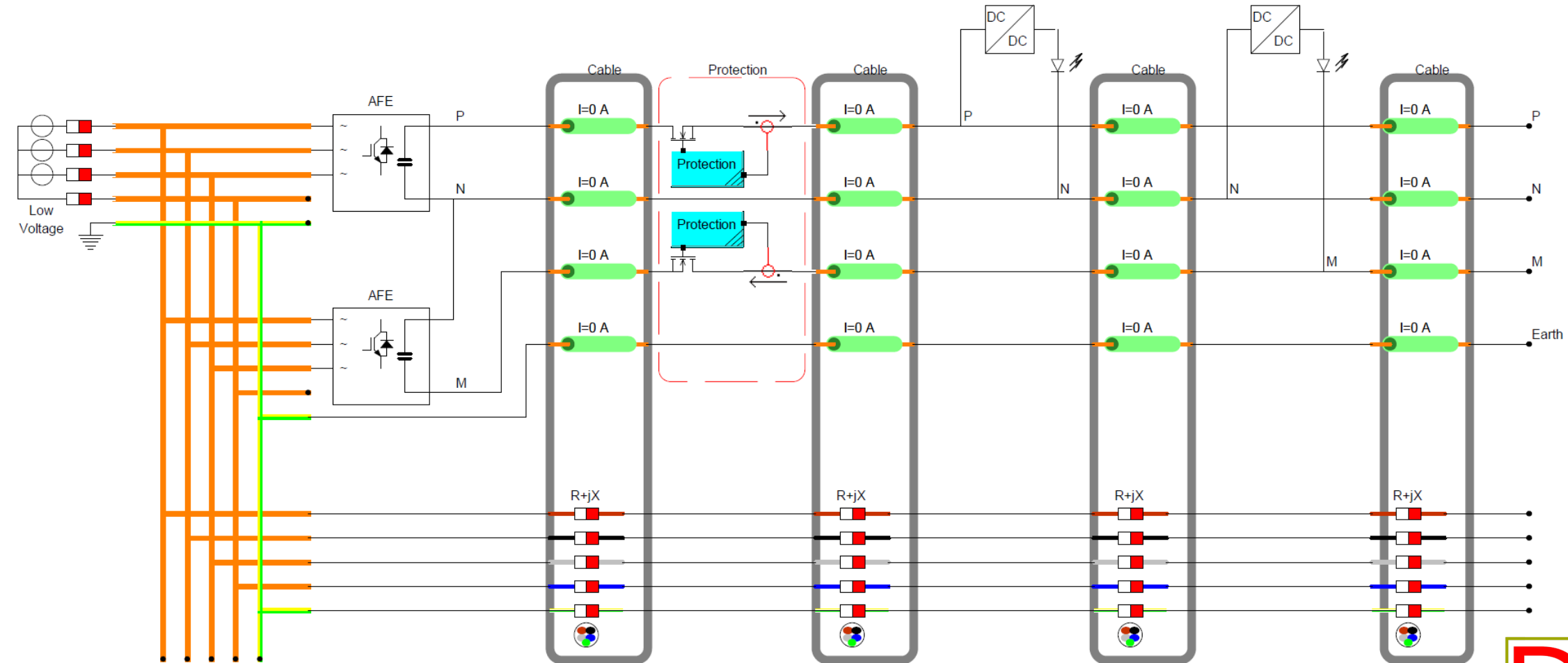
Structure of the DC Grid

Why do we need a DC Grid?

Lower losses is not the reason why we choose DC!

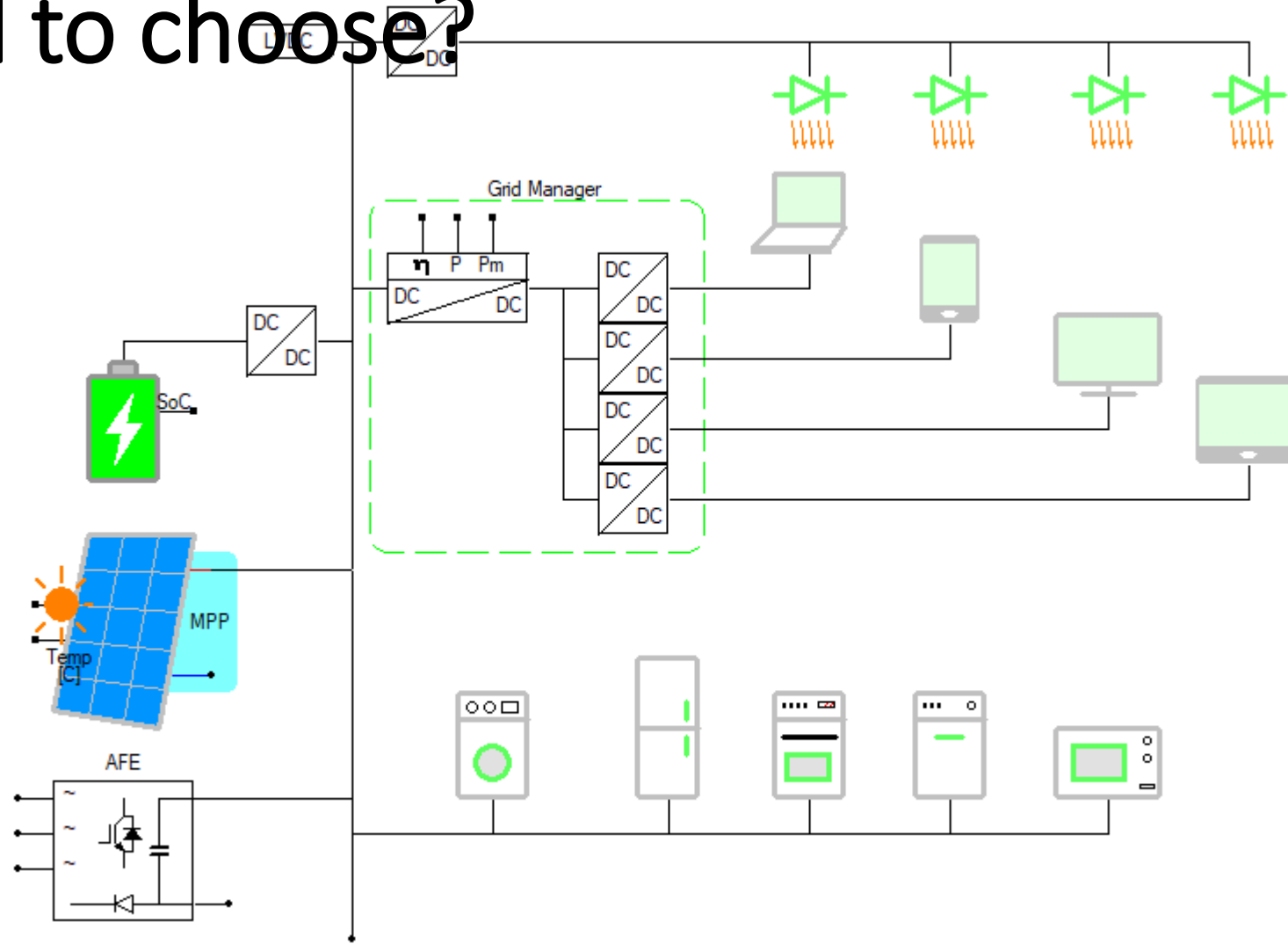


It is not about optimizing components It is optimizing the system!



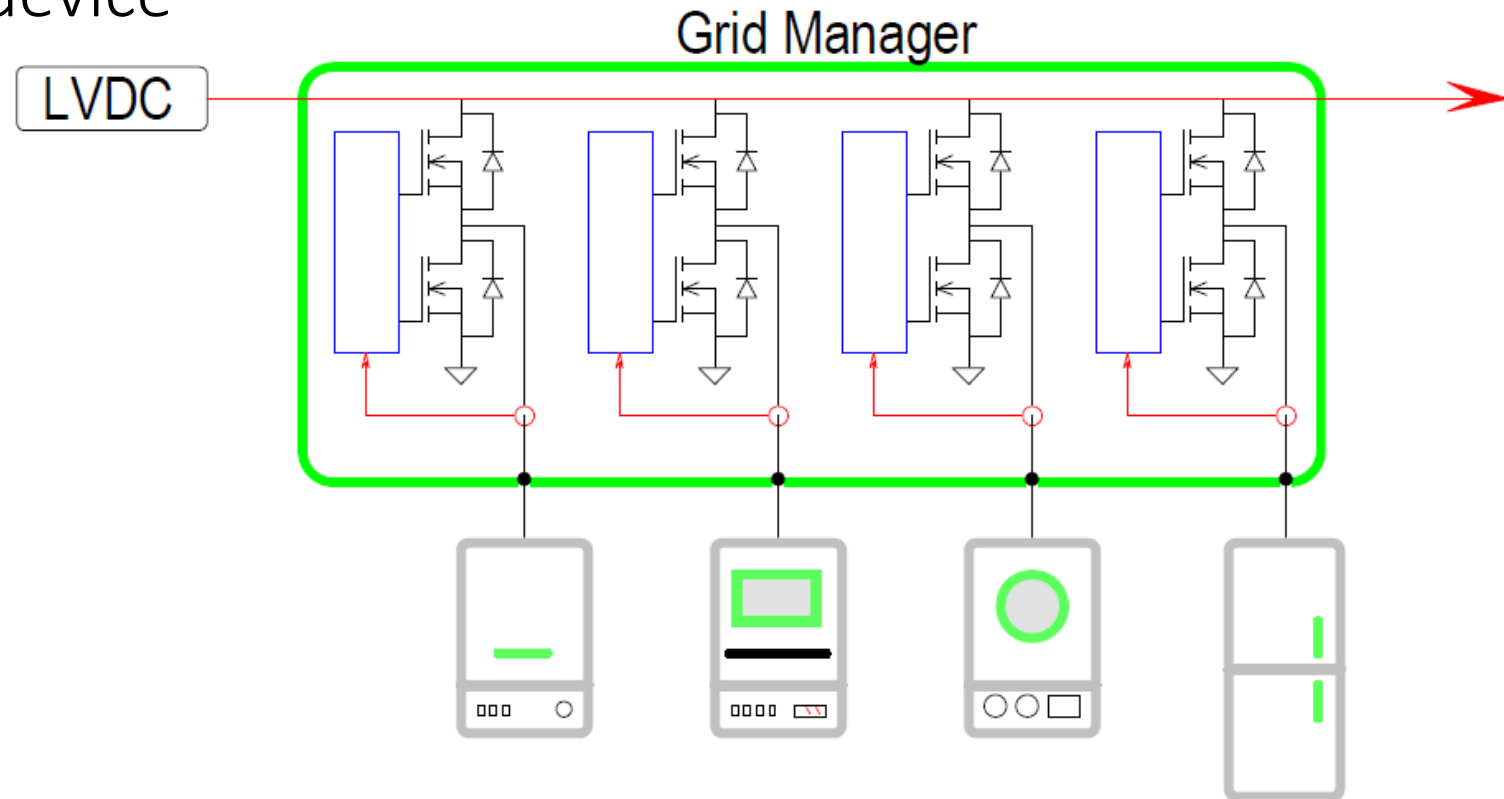
Which grid to choose?

- Centralized
- Decentralized



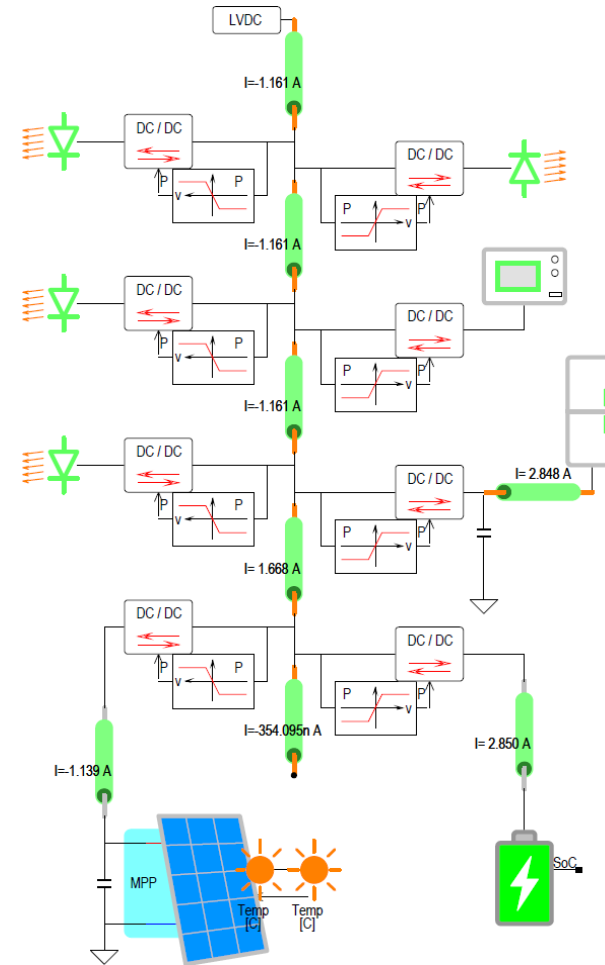
Centralized DC Grid with Grid Manager

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

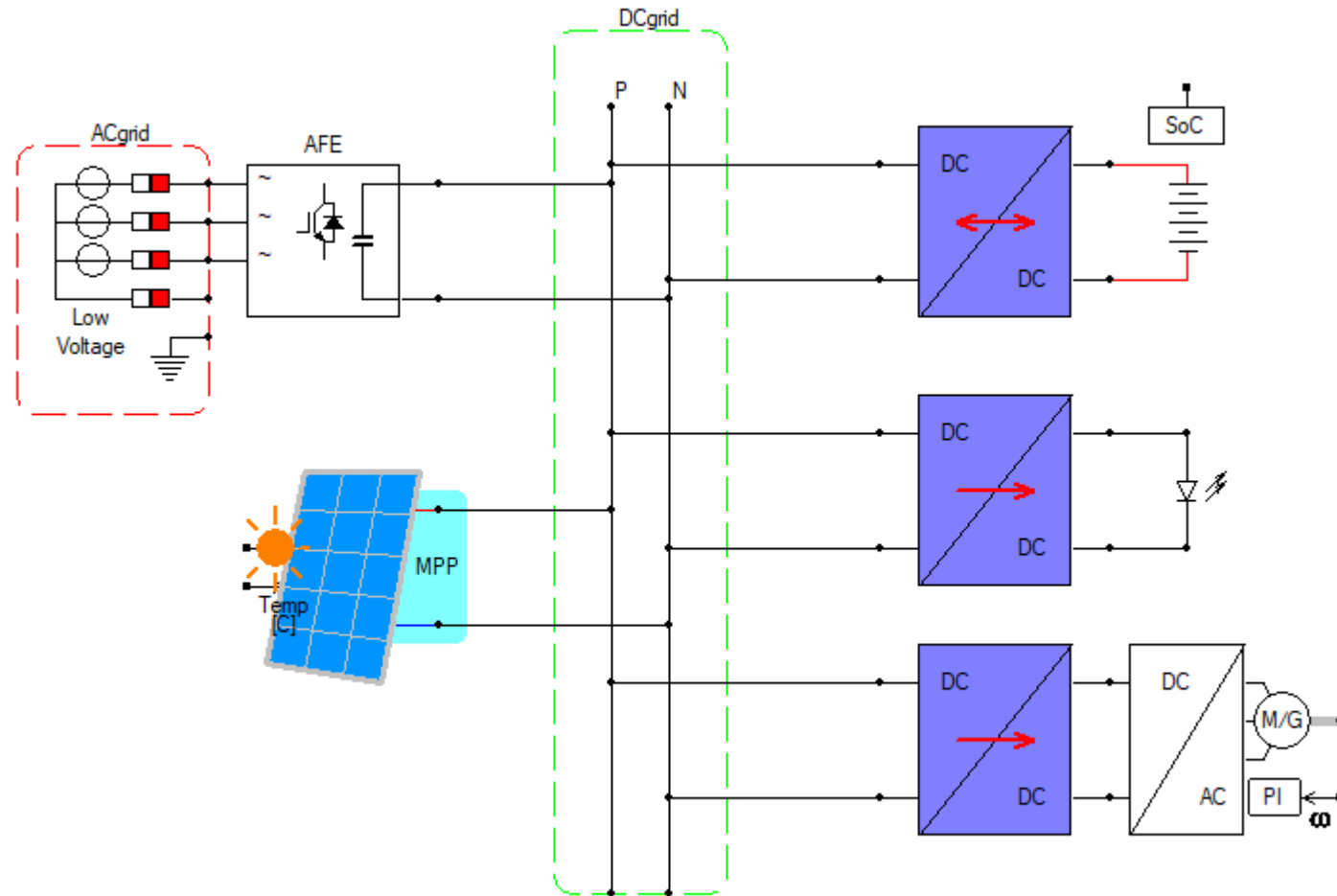


Decentralized DC Grid with Droop Control

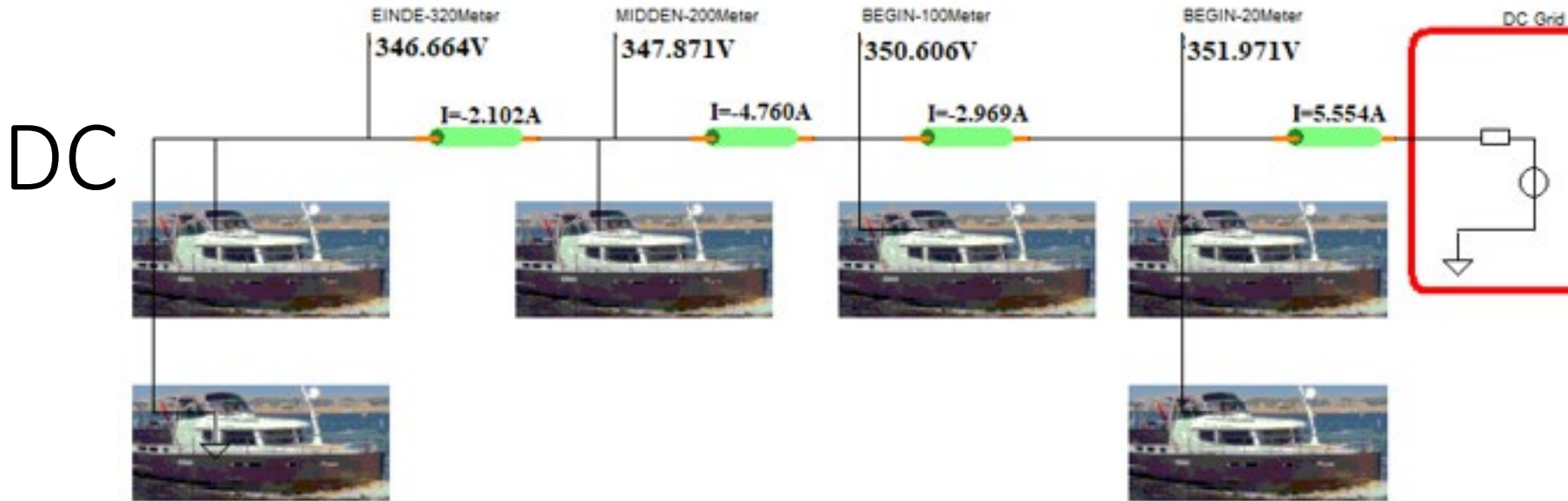
- Droop control per appliance
- DCDC converter per appliance



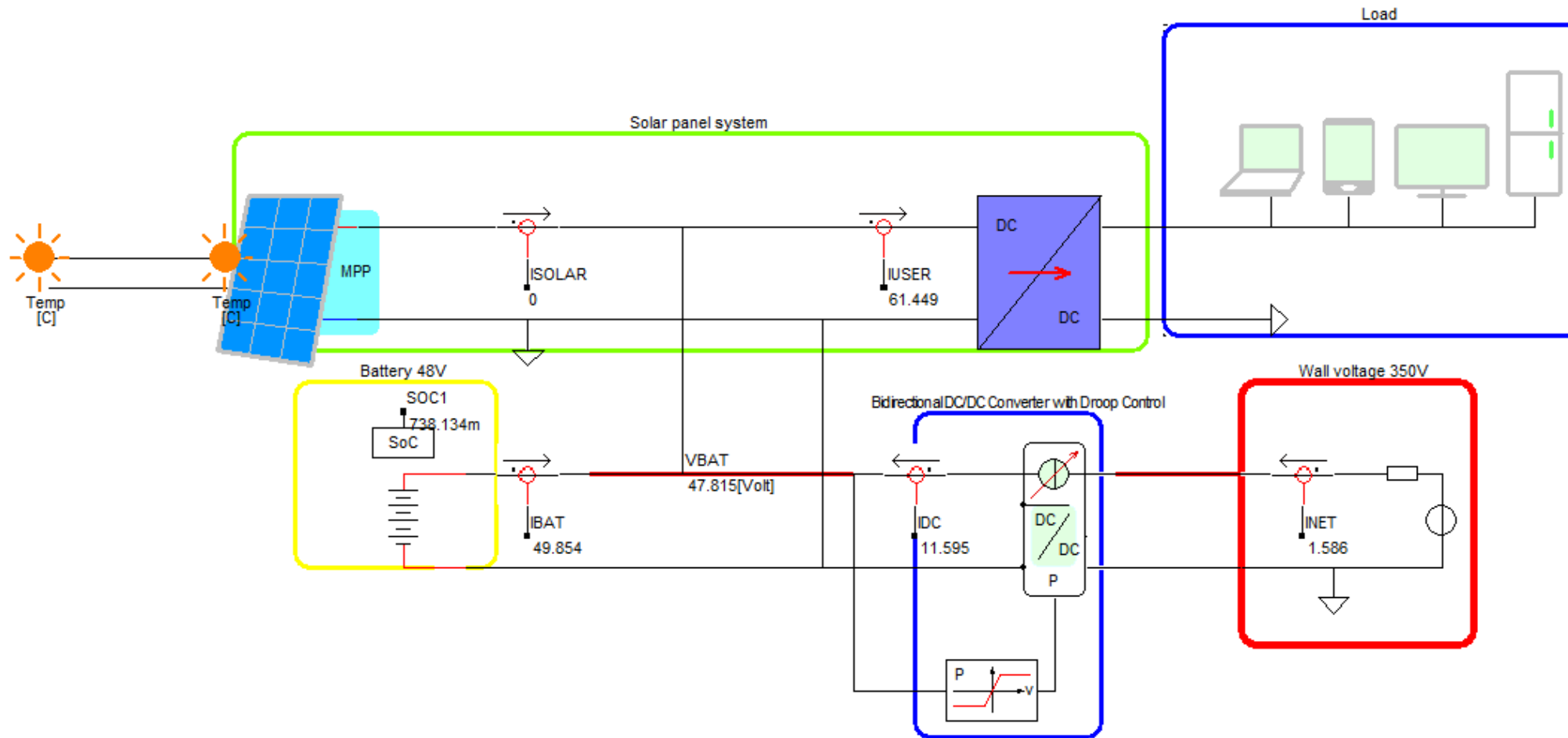
Producers and Consumers are directly coupled



Ships connected to the DC grid



DC Droop control per ship

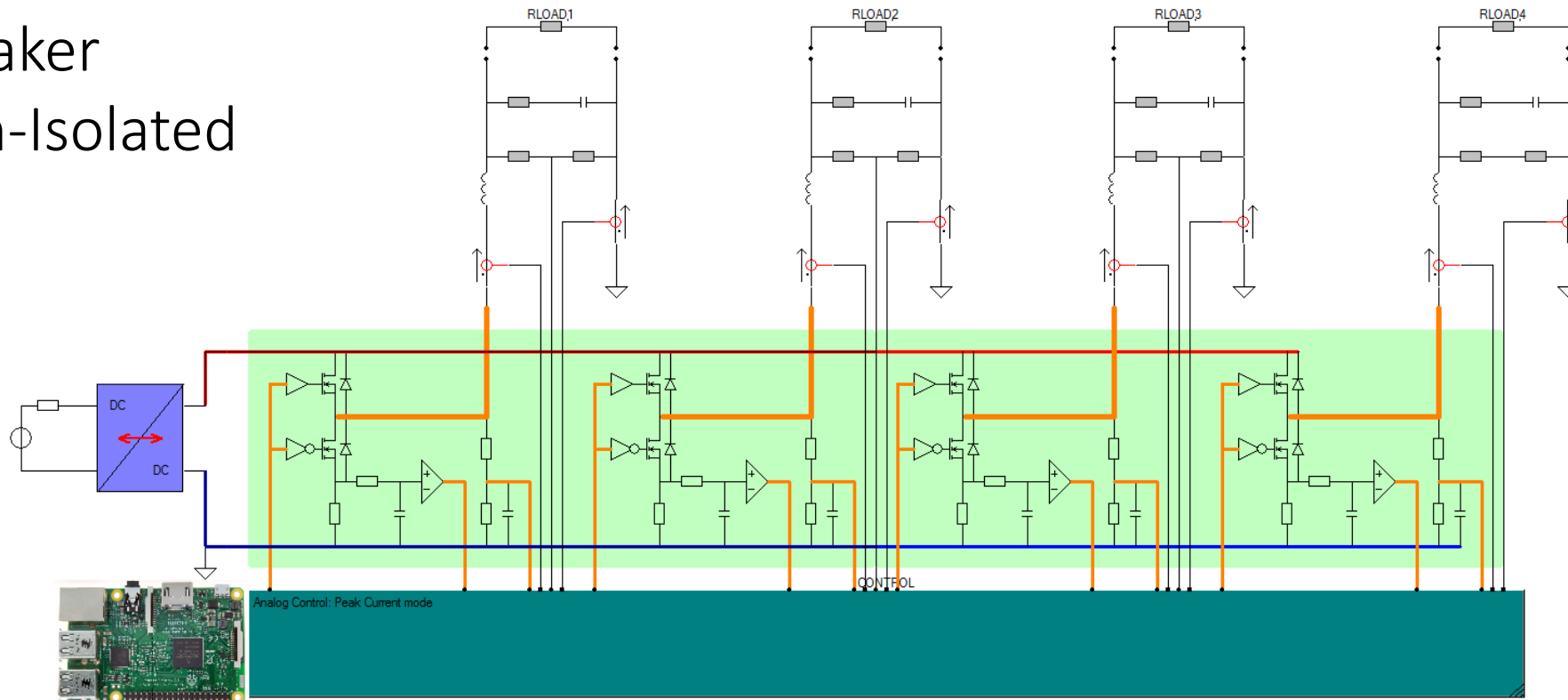


Switching in the DC grid?

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

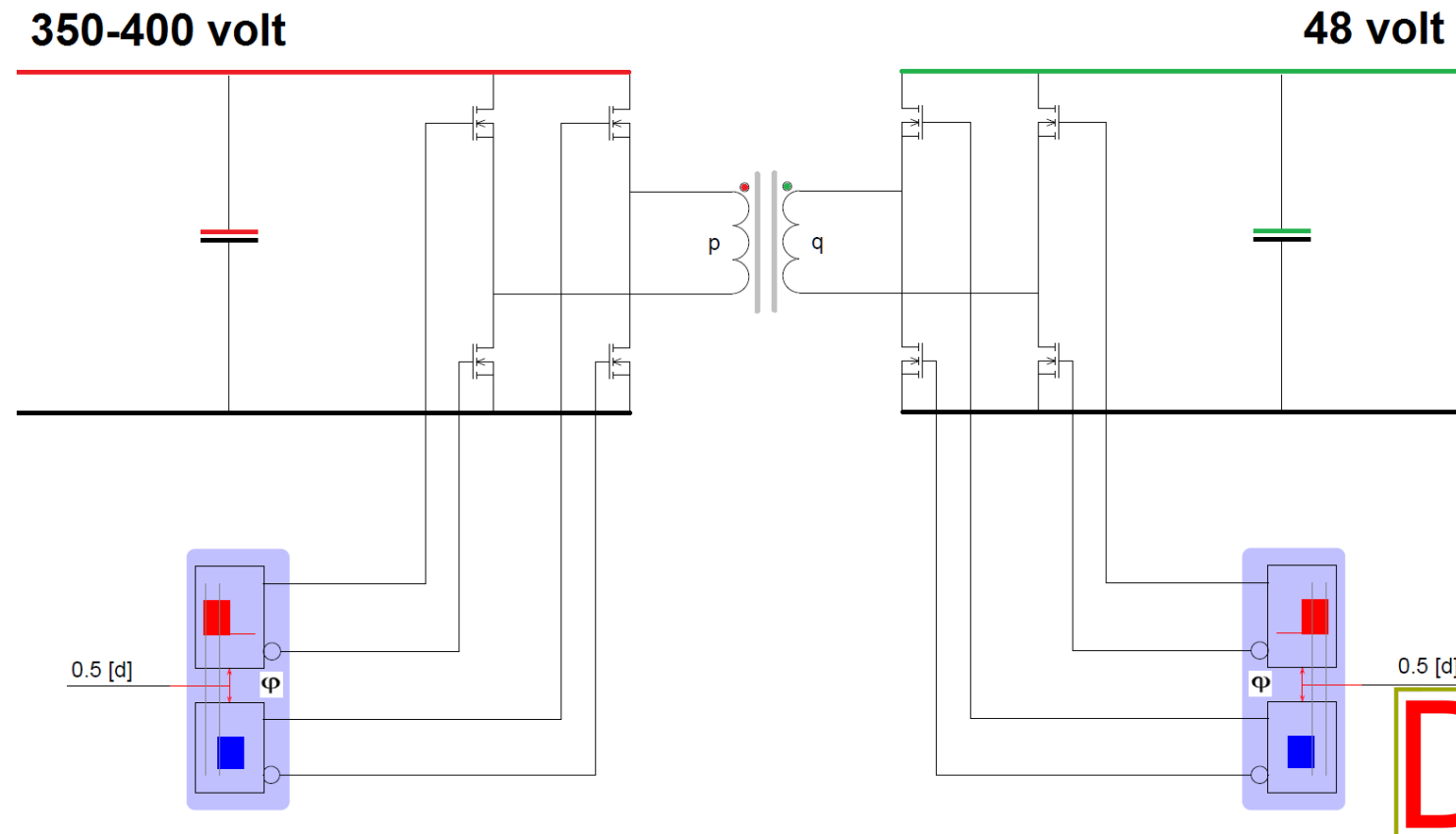
Grid Manager contains multiple Synchronous Buck Converters

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

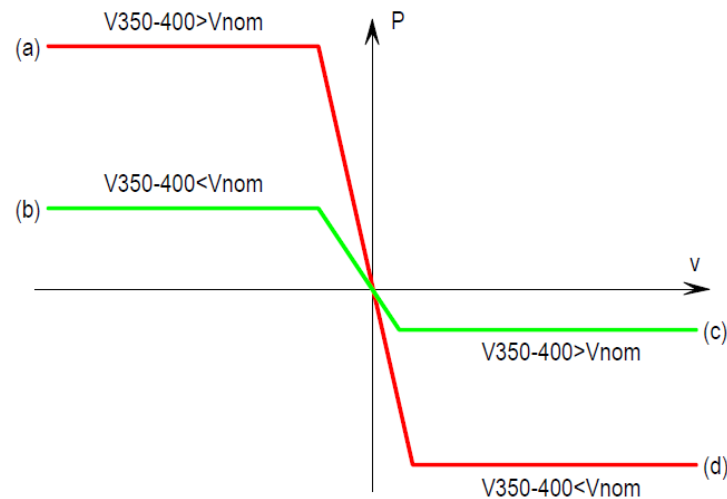
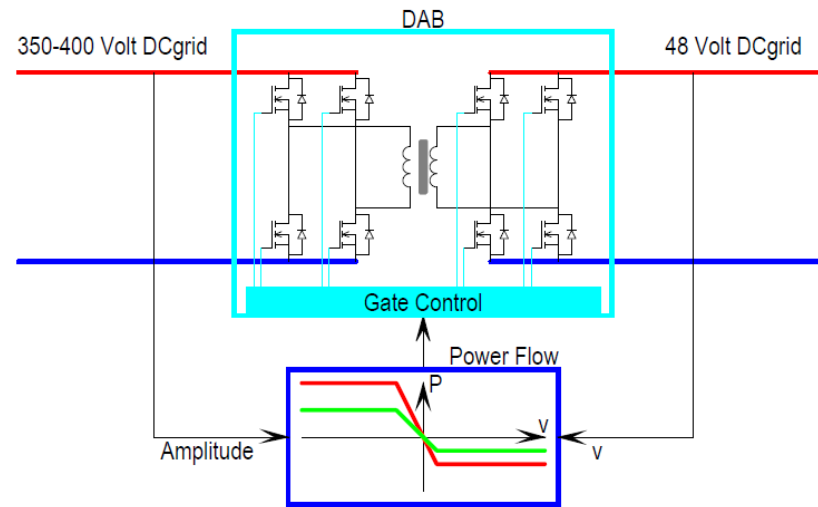


Dual Active Bridge is Isolated

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



Connecting two DC grid with different voltage levels

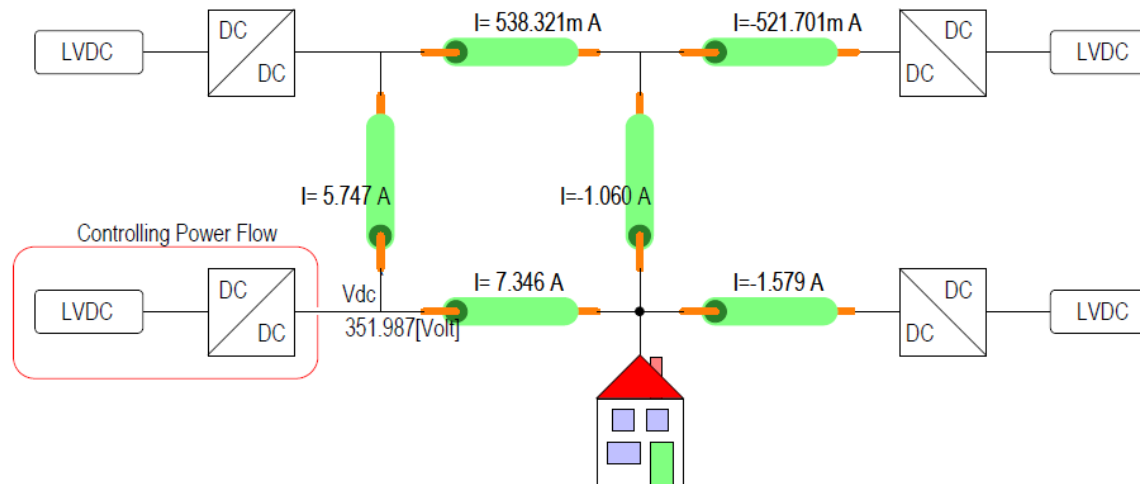
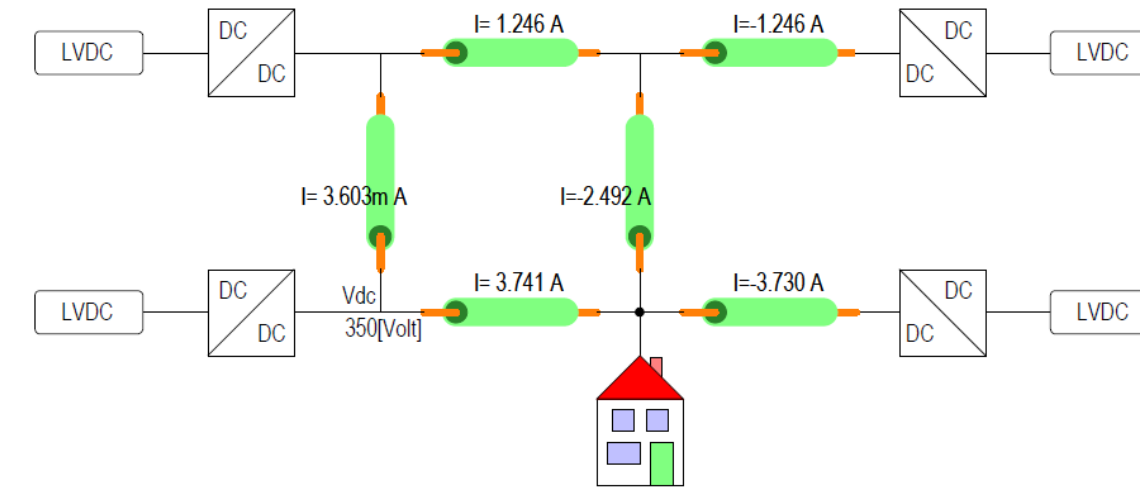


DC grid control?

Control and Power Congestion Management
in the DC Grid

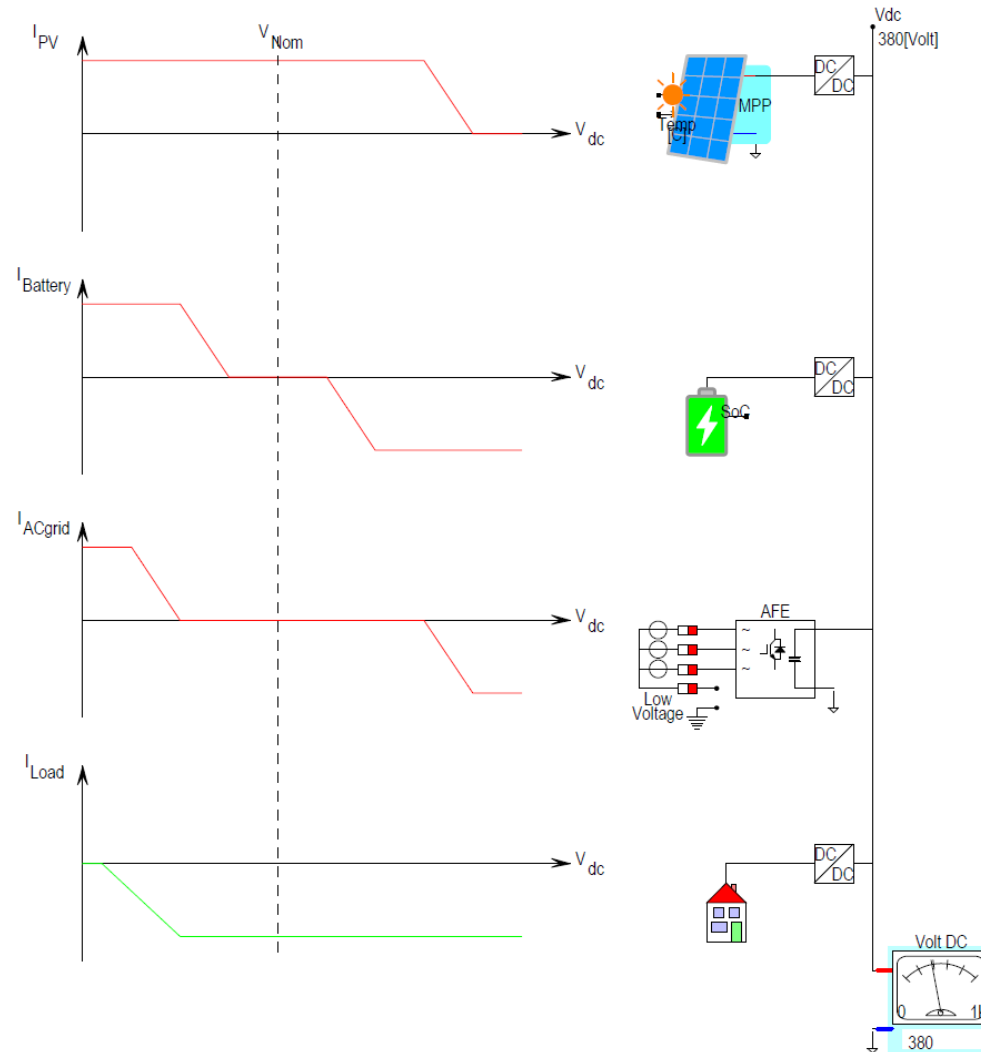
Control the current in a Meshed grid

- Nodal voltage defines current flow
- DCDC converters have losses



Drop Control regulates in a decentralized grid

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

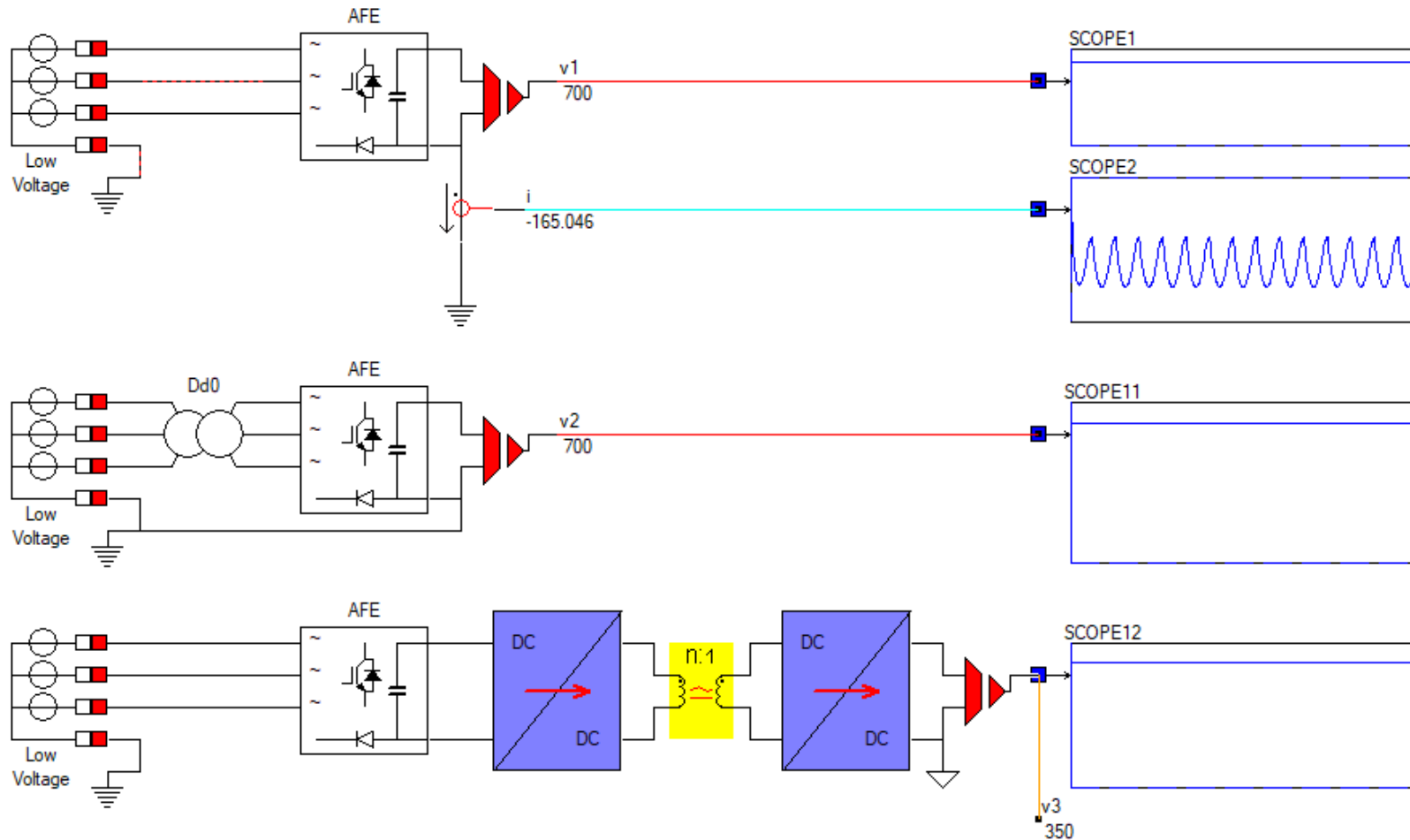


DC grid selectivity and protection?

Protection and/or selectivity
in the DC Grid?

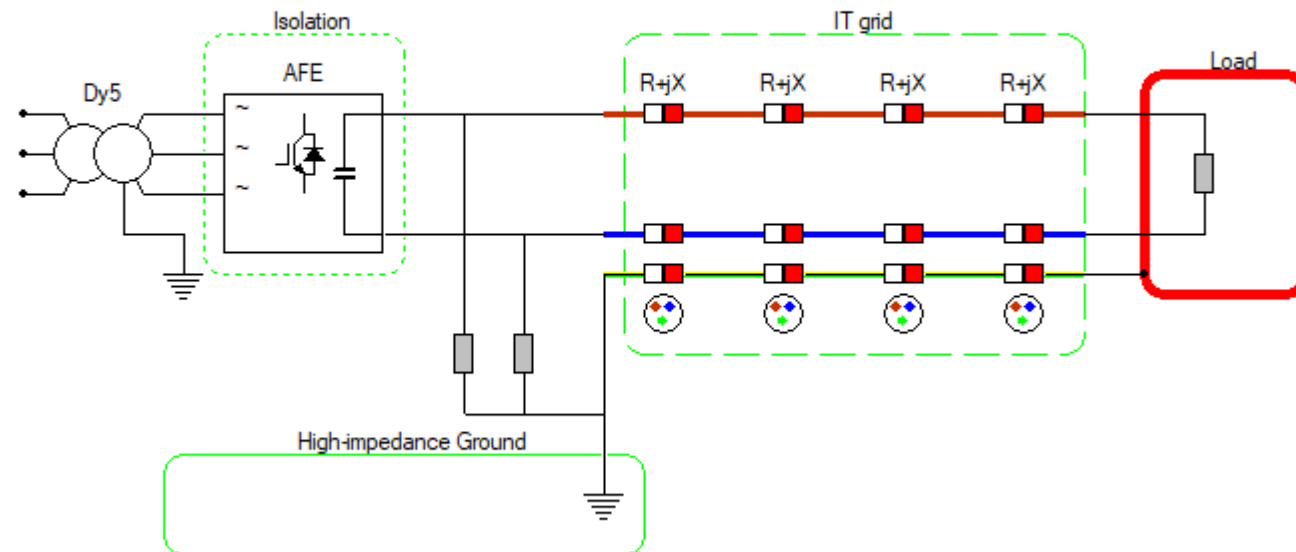


When grounding, the DC grid has to be isolated from the AC grid

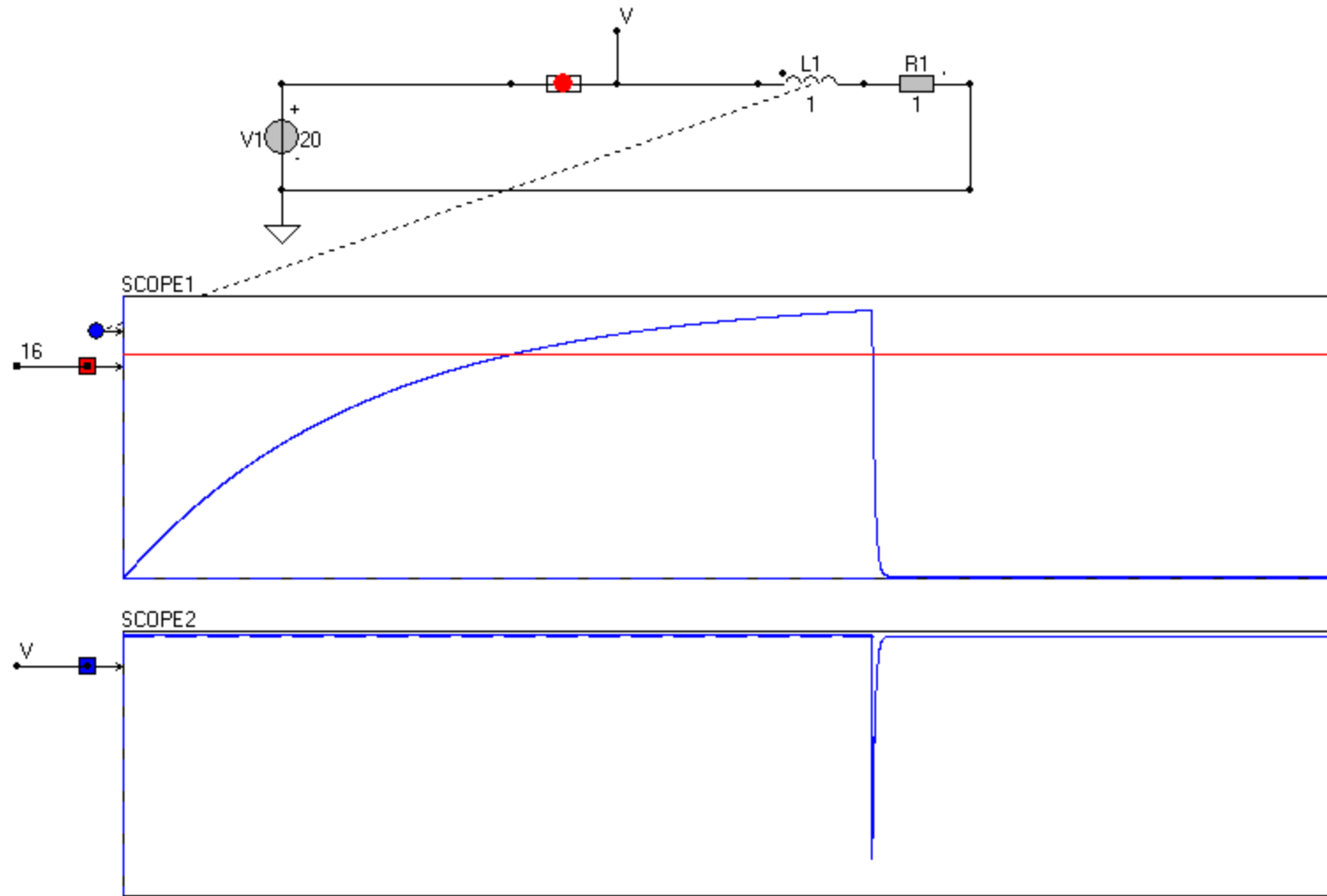


Grid system?

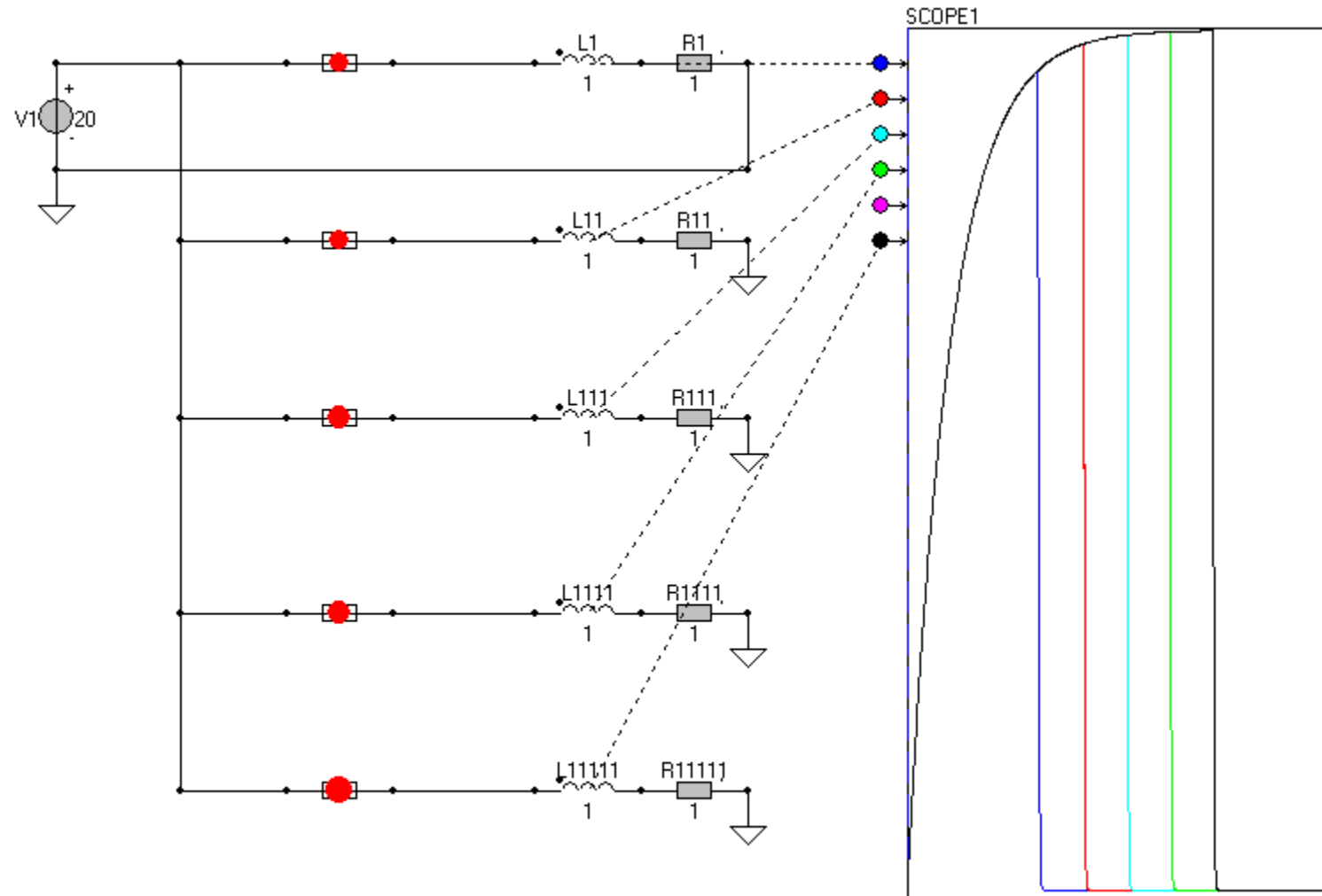
- You can choose an isolated Grid IT to implement earth leakage detection,
- but your grid is floating!



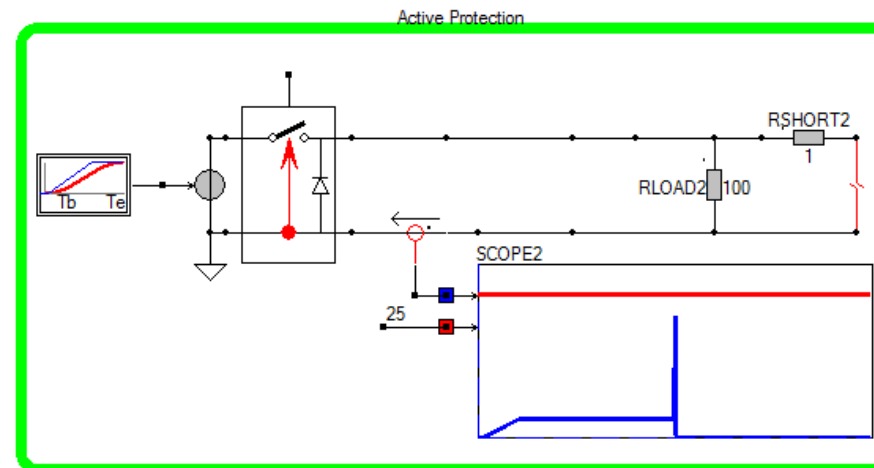
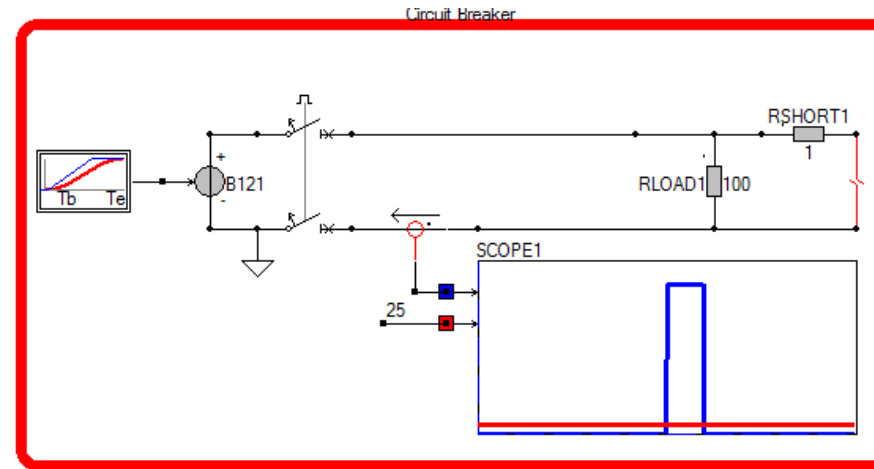
Fuse?



Fuse?



RoCoC Rate of Change of Current



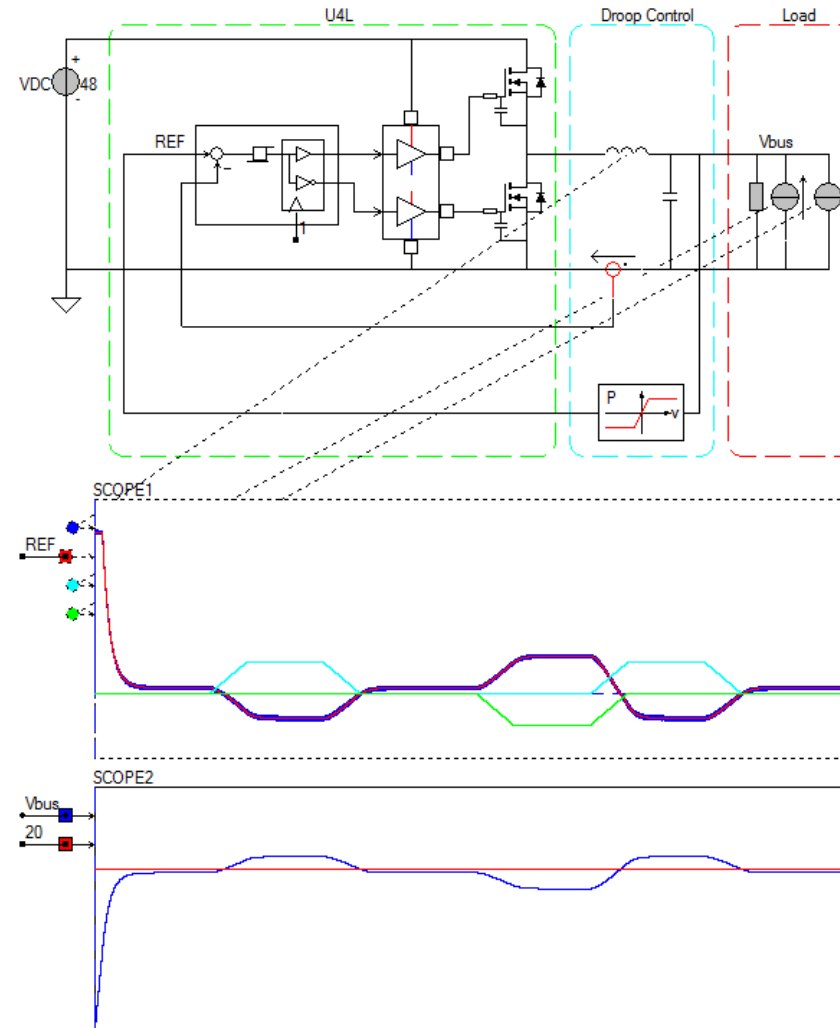
DC grid stability?

How to predict and ensure stability in the
DC Grid



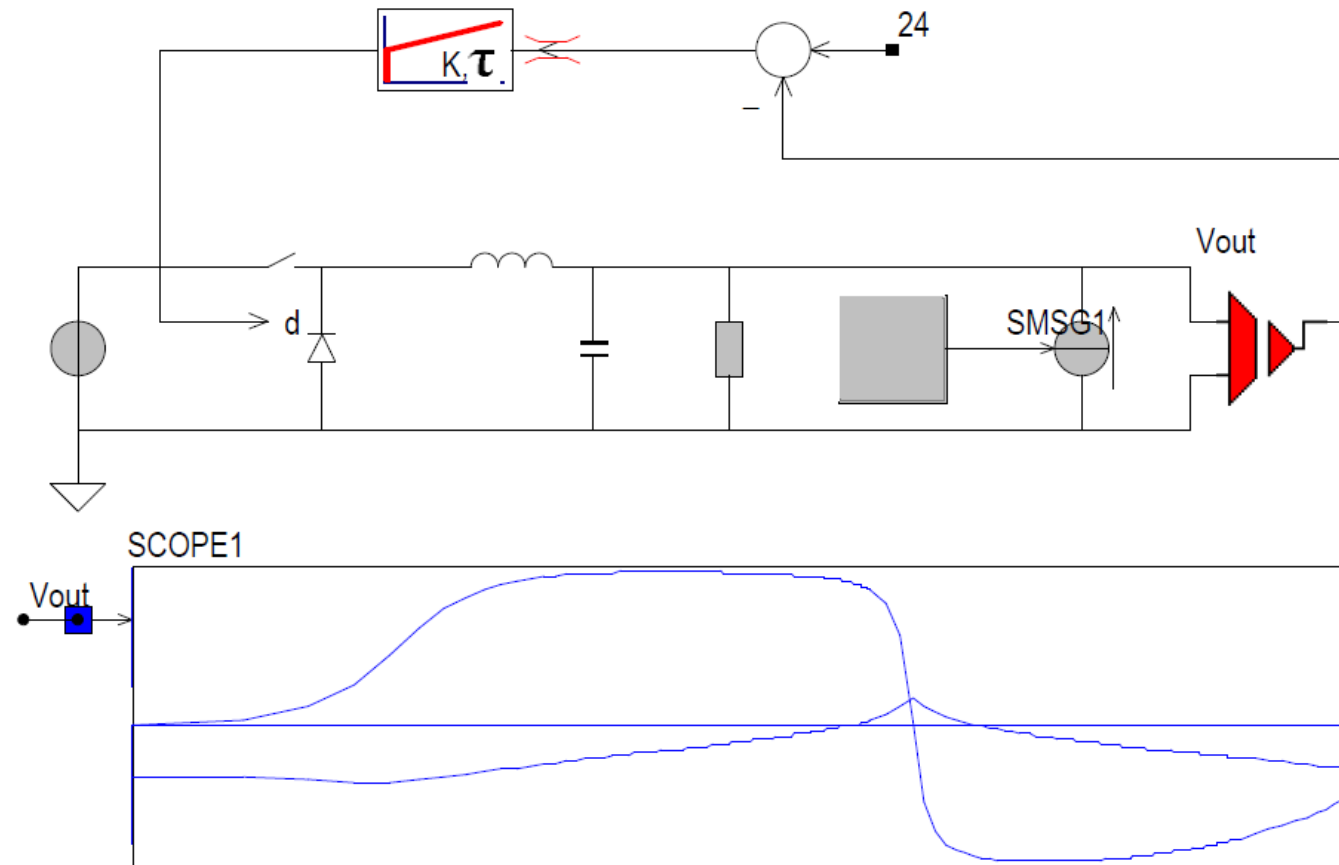
Static stability depends in Droop Control Characteristics

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



Dynamic stability depends on input and output impedance

- $Z_{out} < Z_{in}$
- Middlebrooks Stability Criterion



Conclusion: DC Grid: Protect or Control?

- Centralized or Decentralized
- Control
- Protection
- Stability



Thanks for your attention!

www.dc-lab.org