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CaspoC



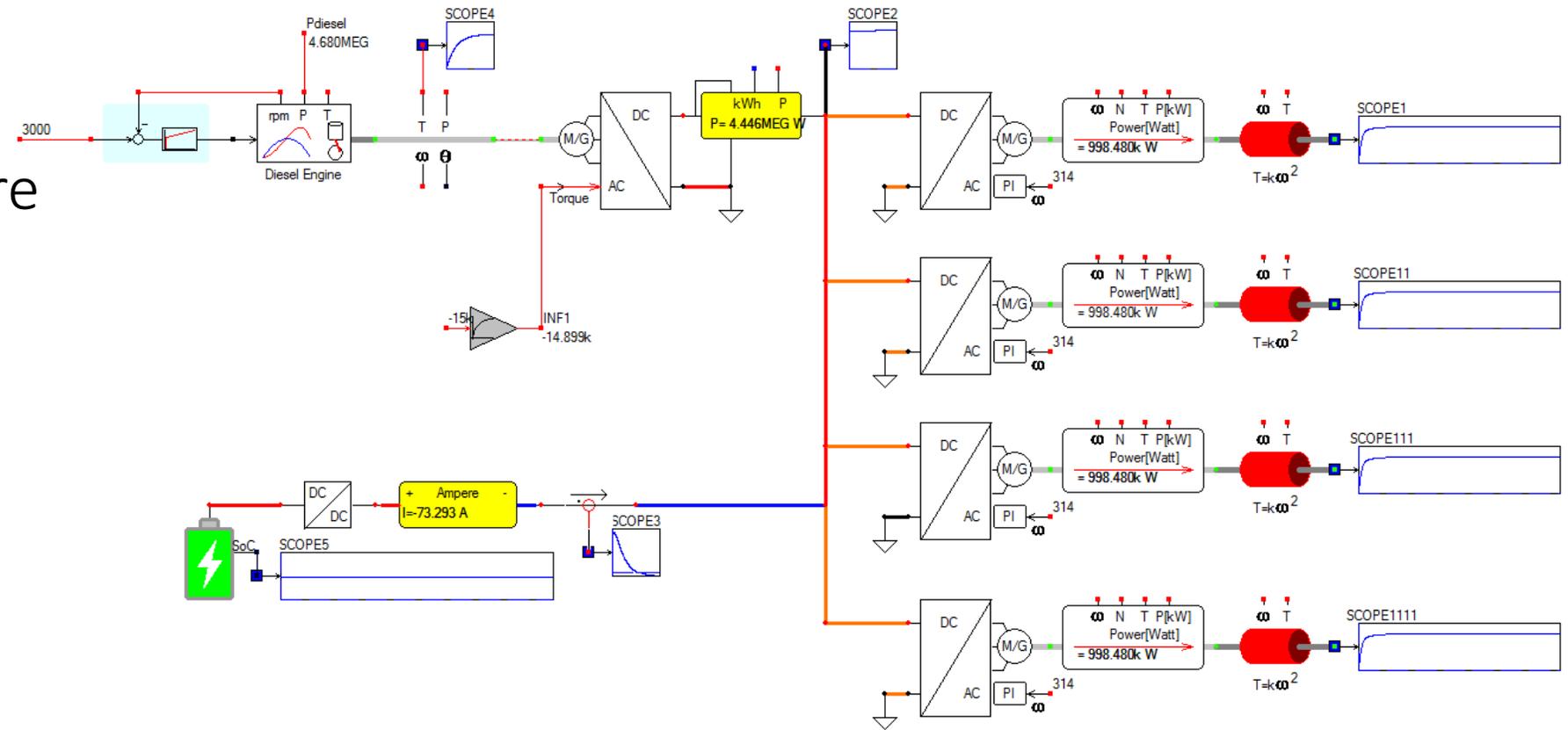
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ENERGY STORAGE
EVENT 2022



Contents

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



DC grid structure?

Structure of the DC Grid



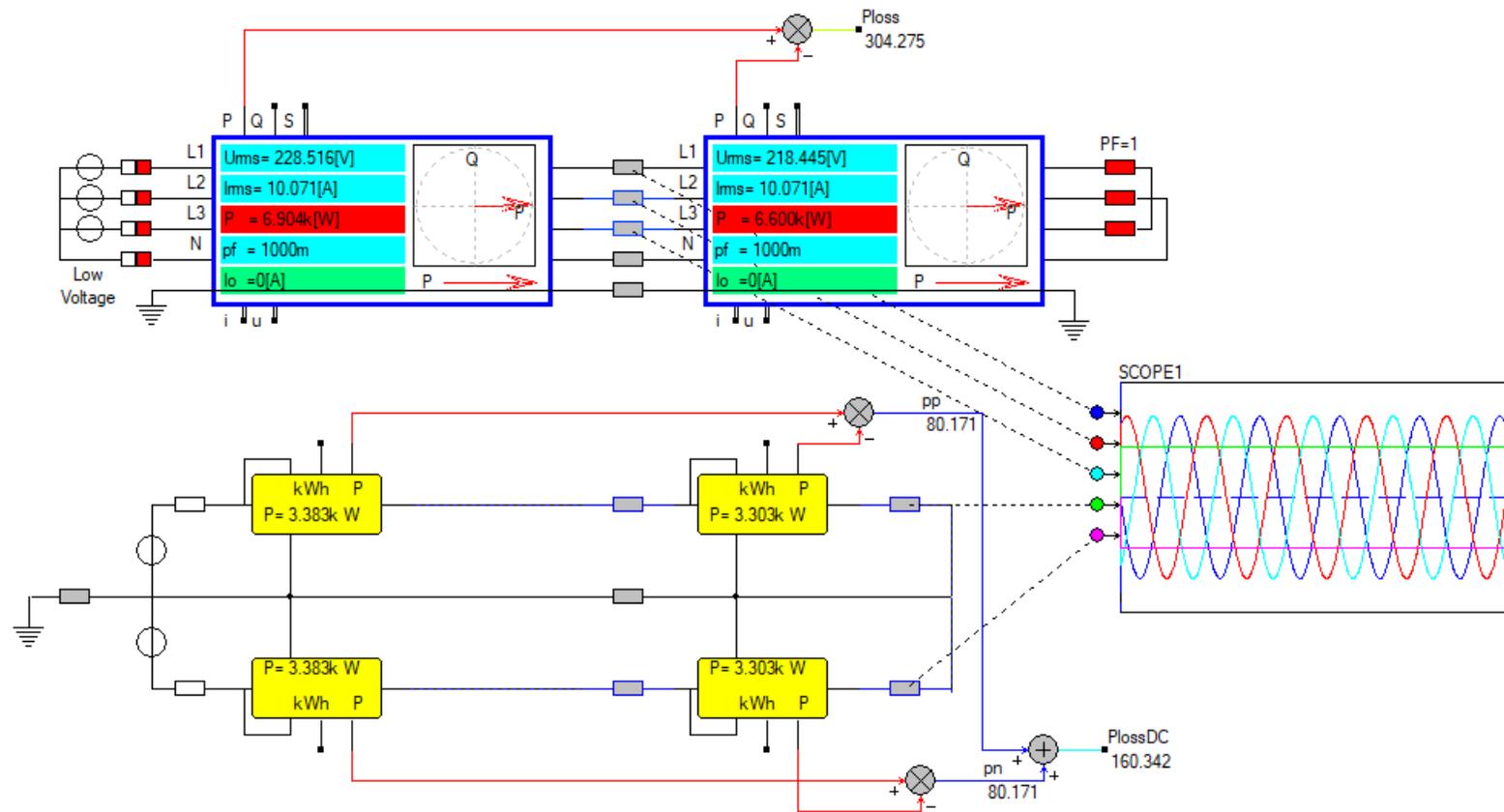
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Why do we need a DC Grid?

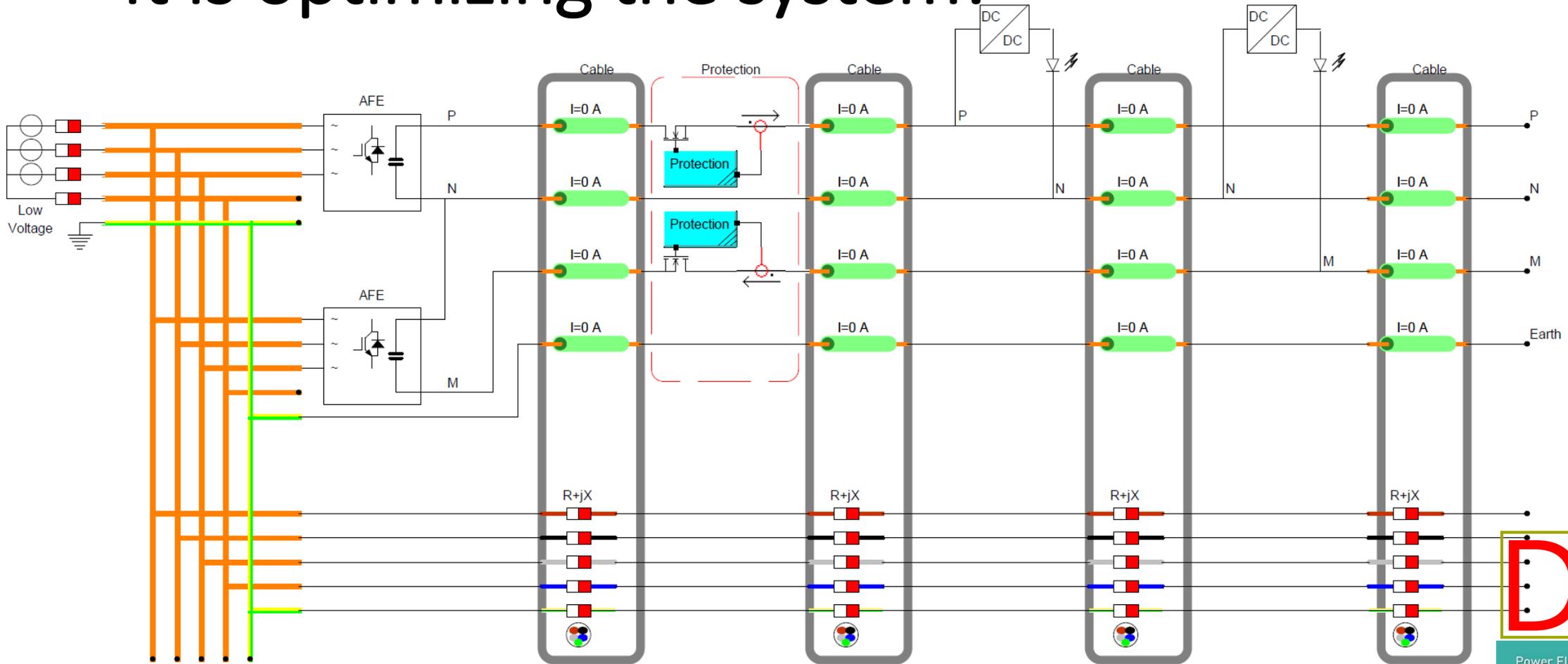
Lower losses is not the reason why we choose DC!



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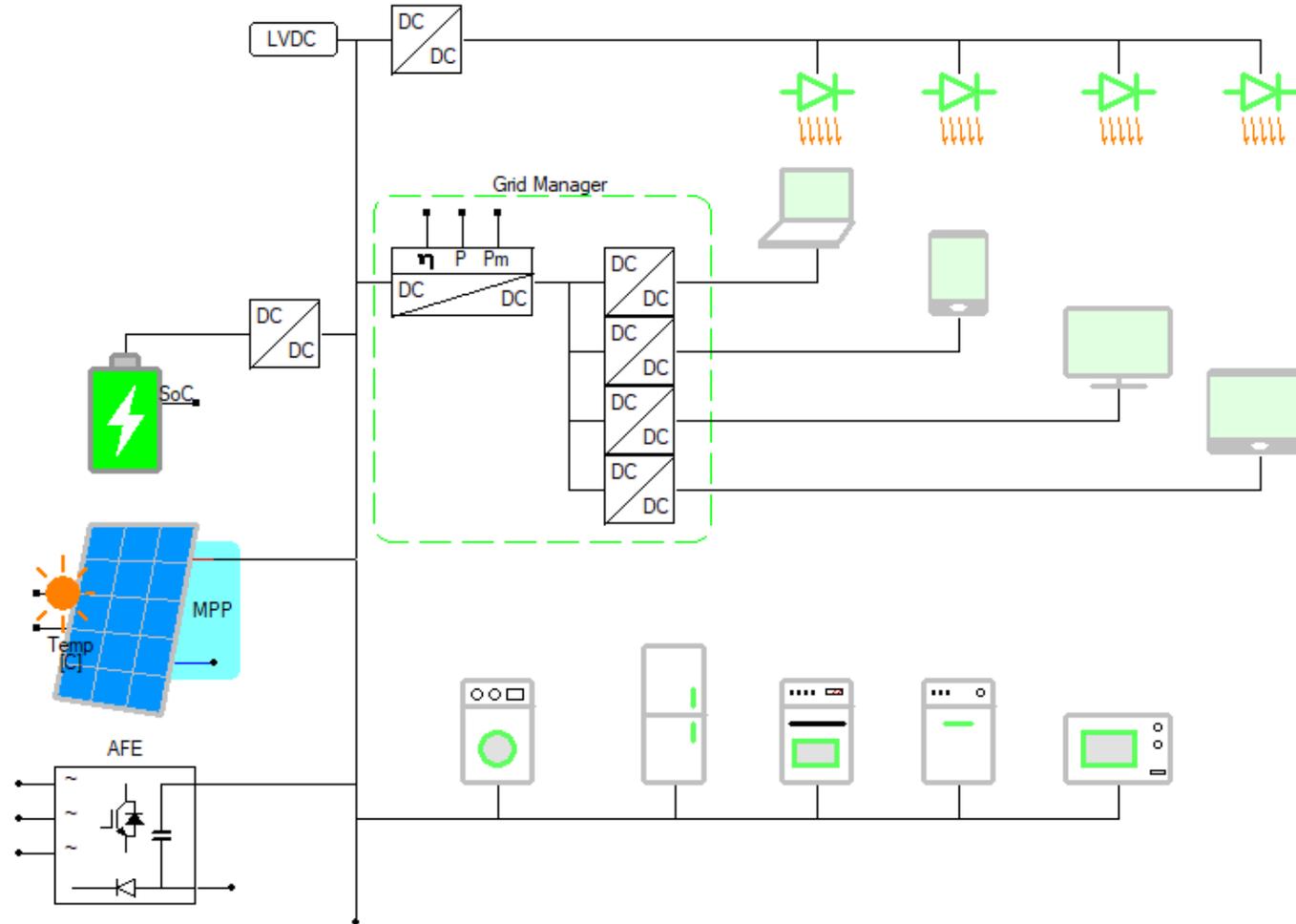
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It is not about optimizing components It is optimizing the system!



Which grid to choose?

- Centralized
- Decentralized



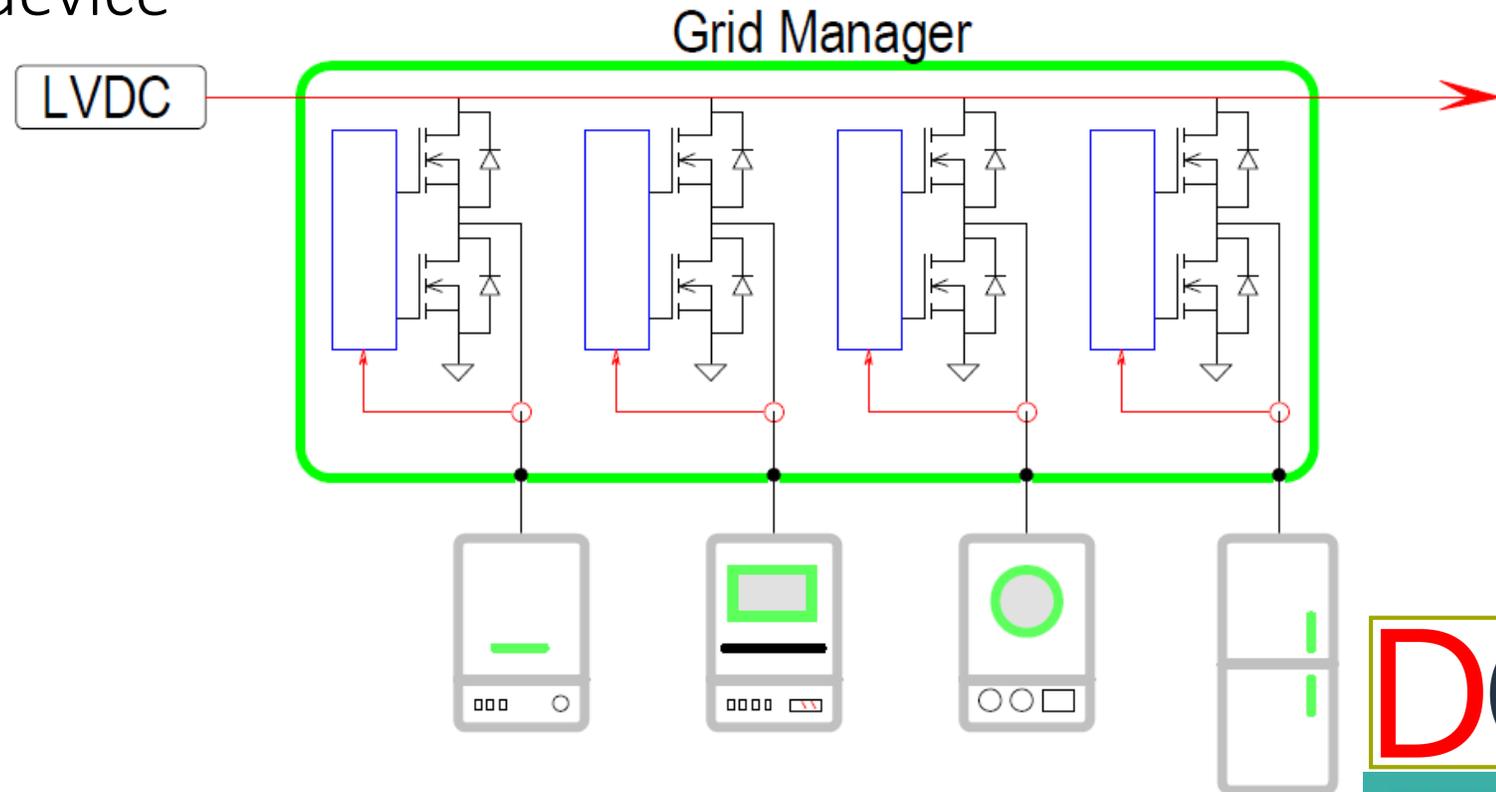
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Centralized DC Grid with Grid Manager

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

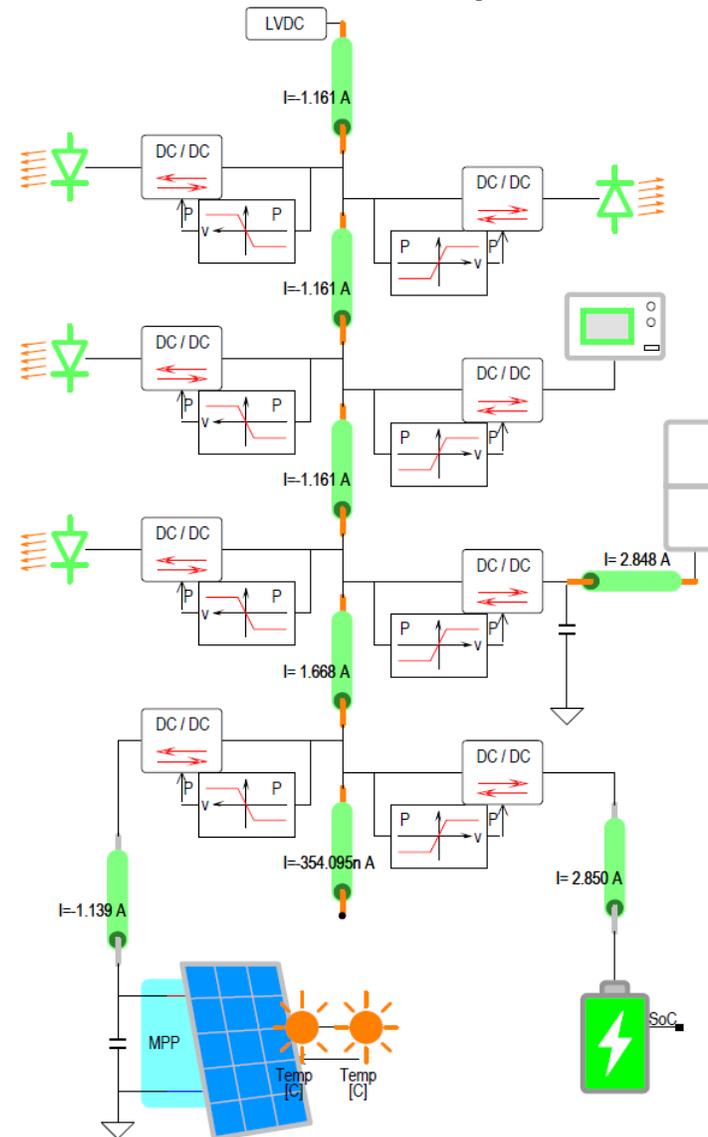


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Decentralized DC Grid with Droop Control

- Droop control per appliance
- DCDC converter per appliance

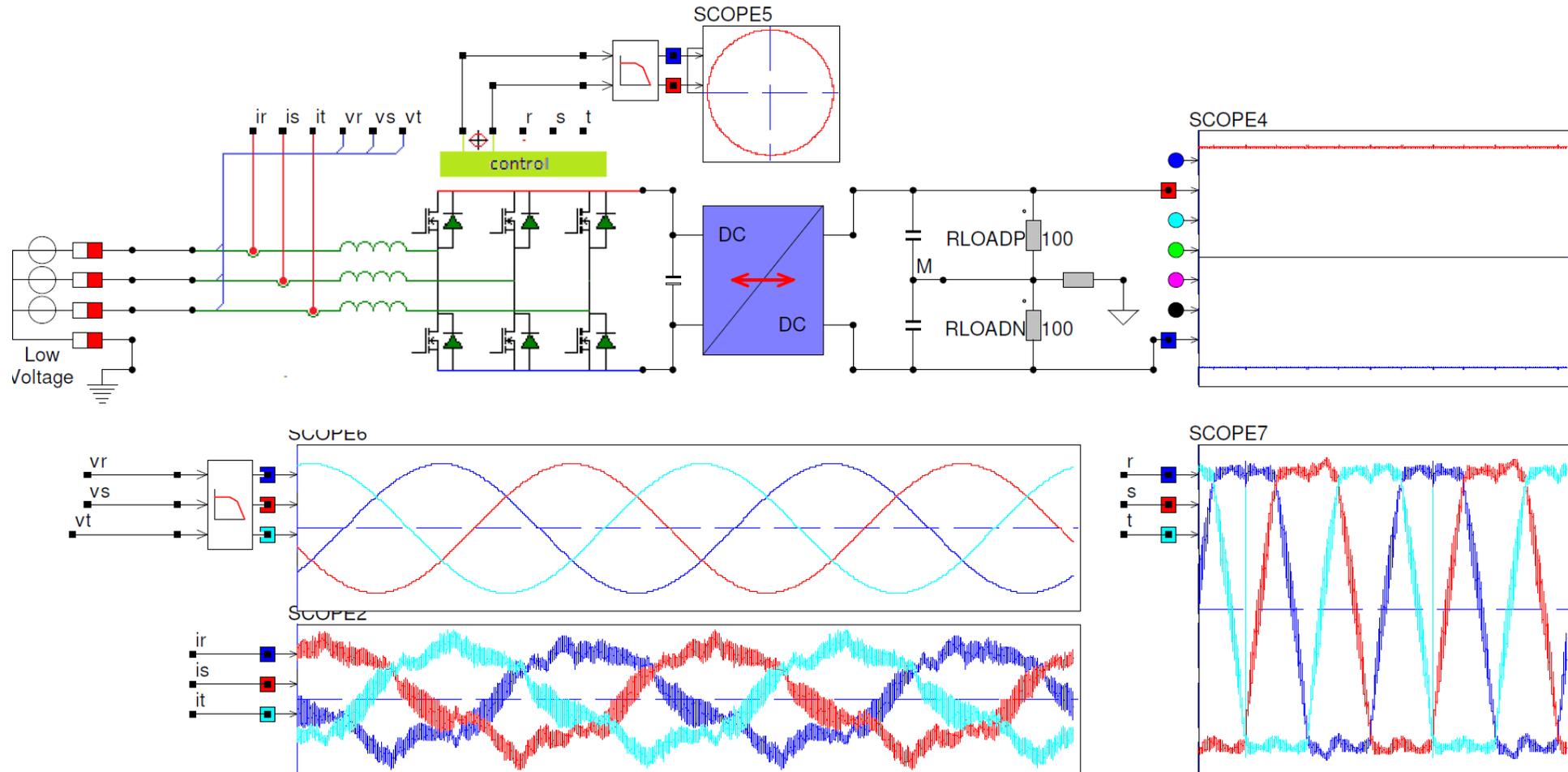


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Connection to existing AC Grid?

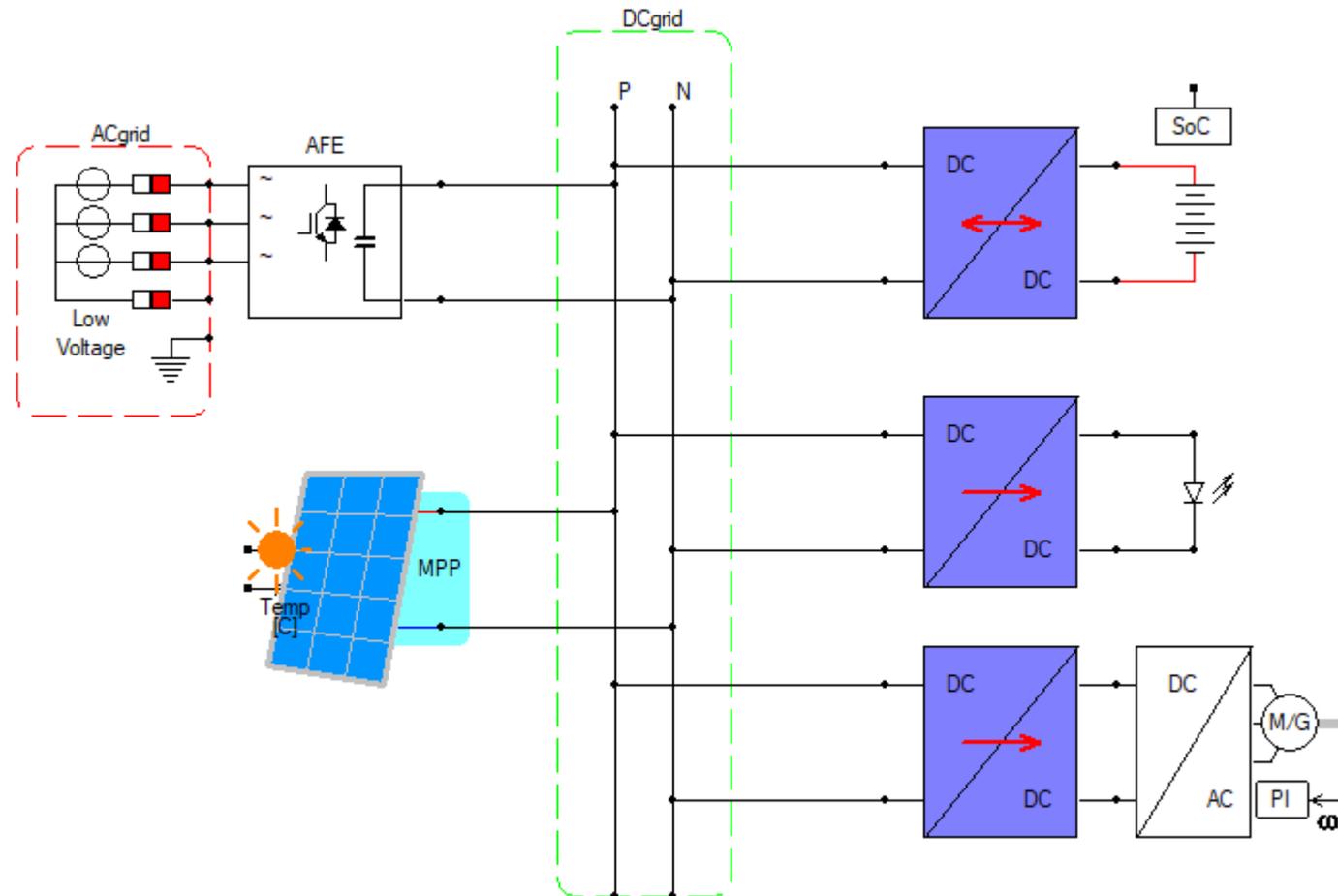


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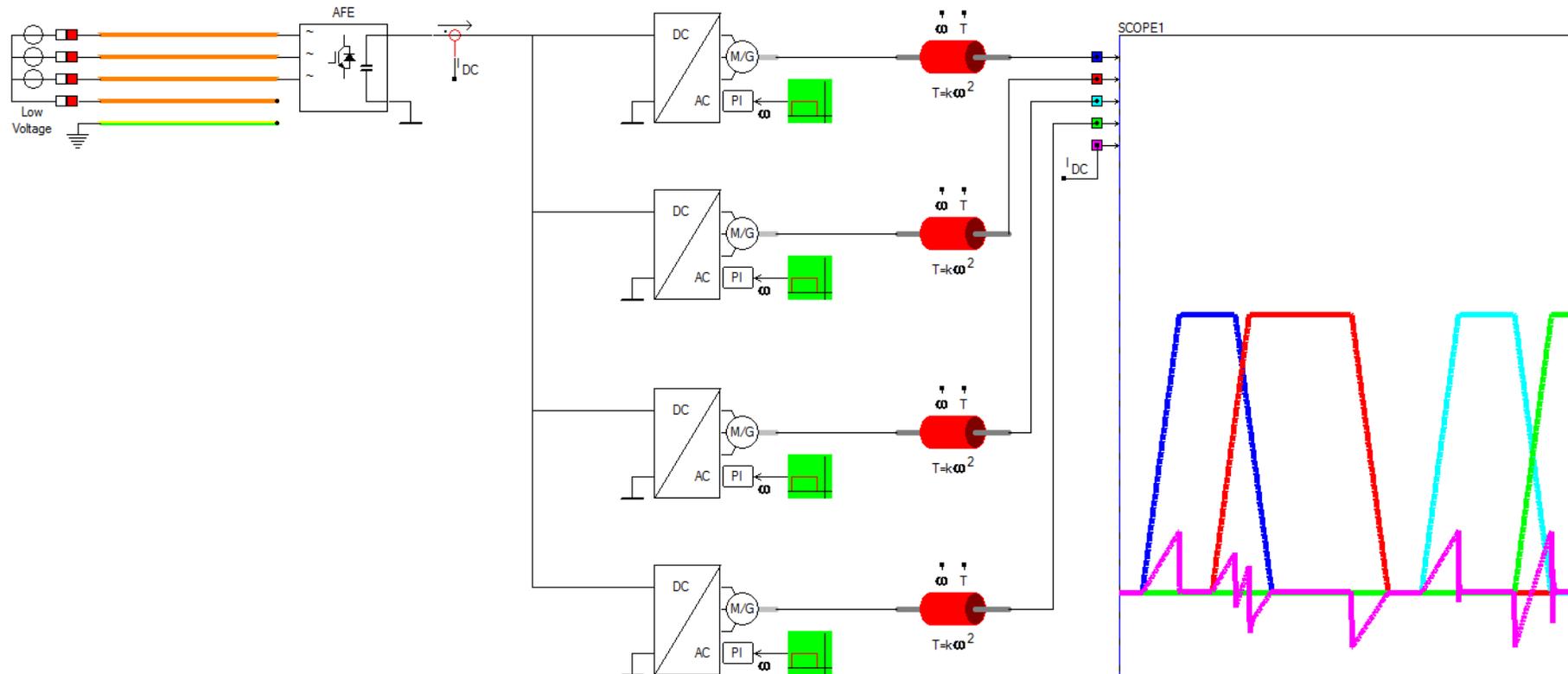
Producers and Consumers are directly coupled



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Exchange of Drive and Brake Energy



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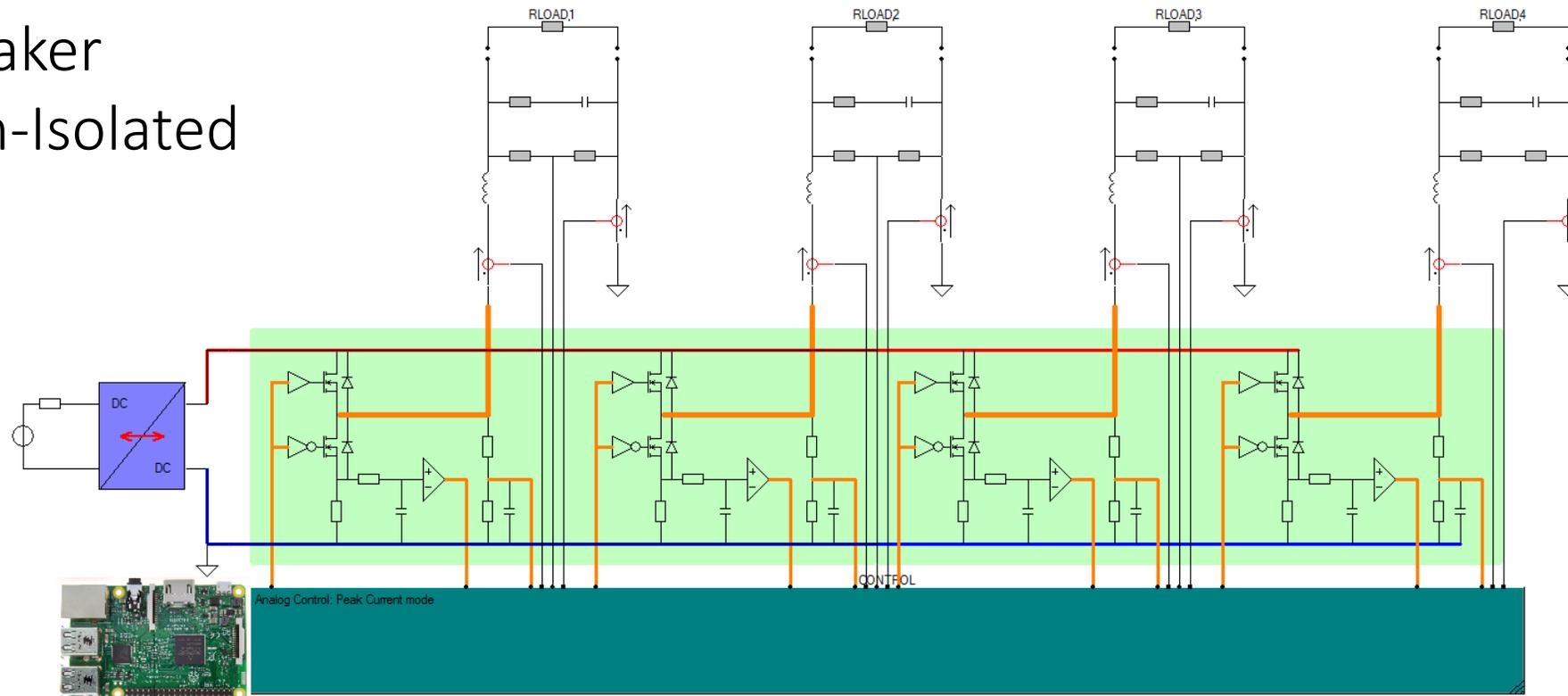
Switching in the DC grid?

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

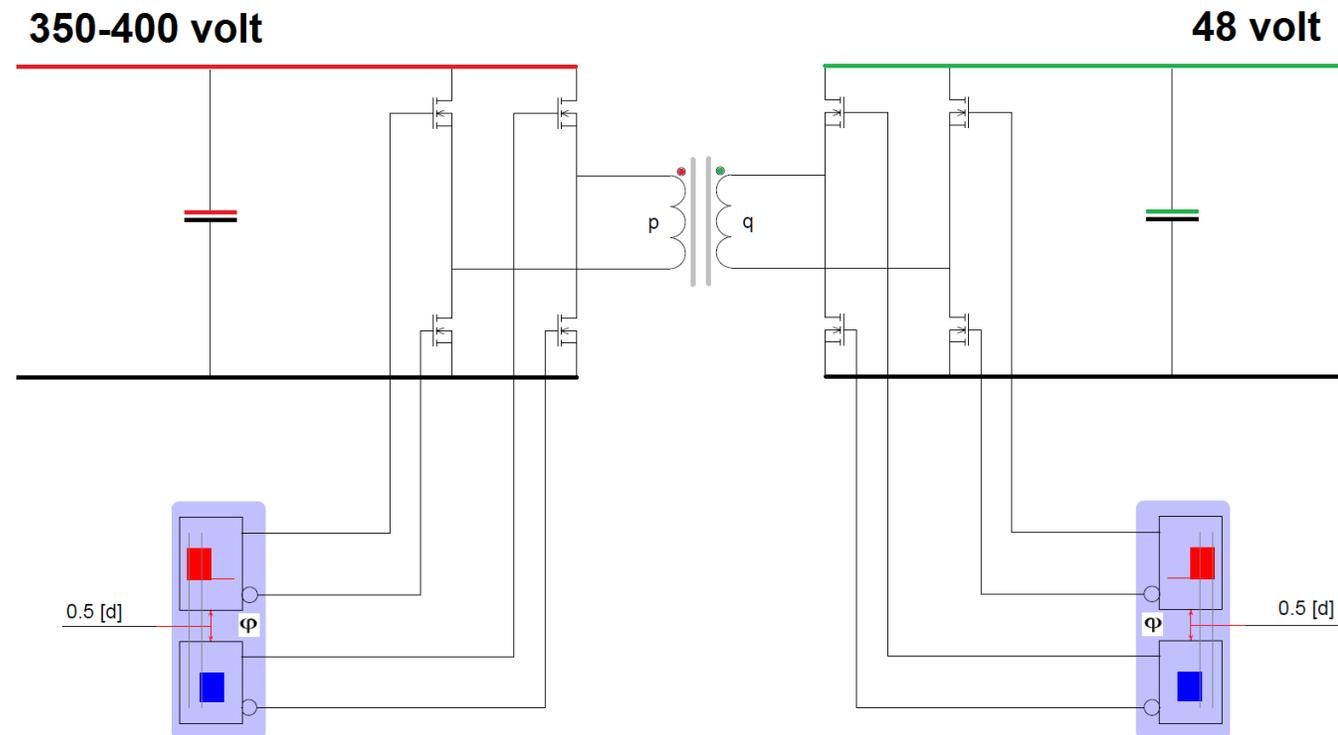


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Dual Active Bridge is Isolated

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

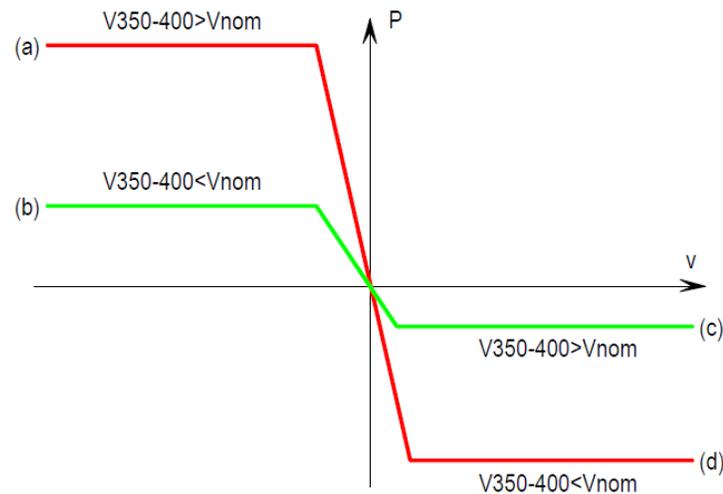
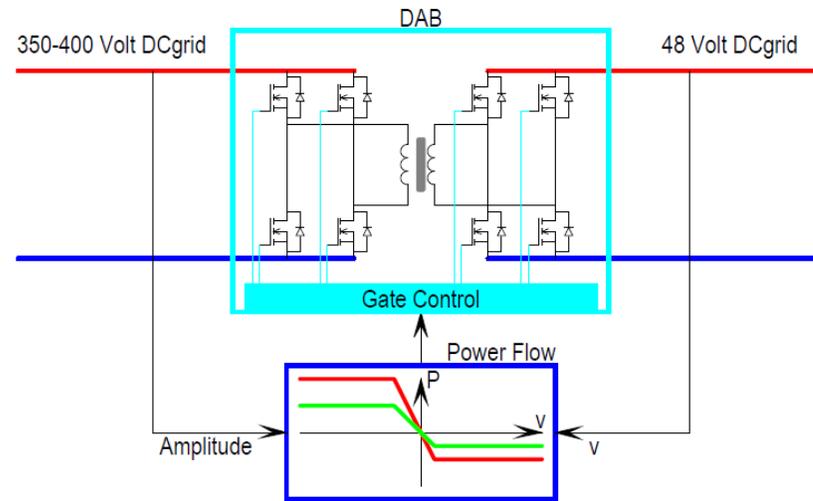


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Connecting two DC grid with different voltage levels



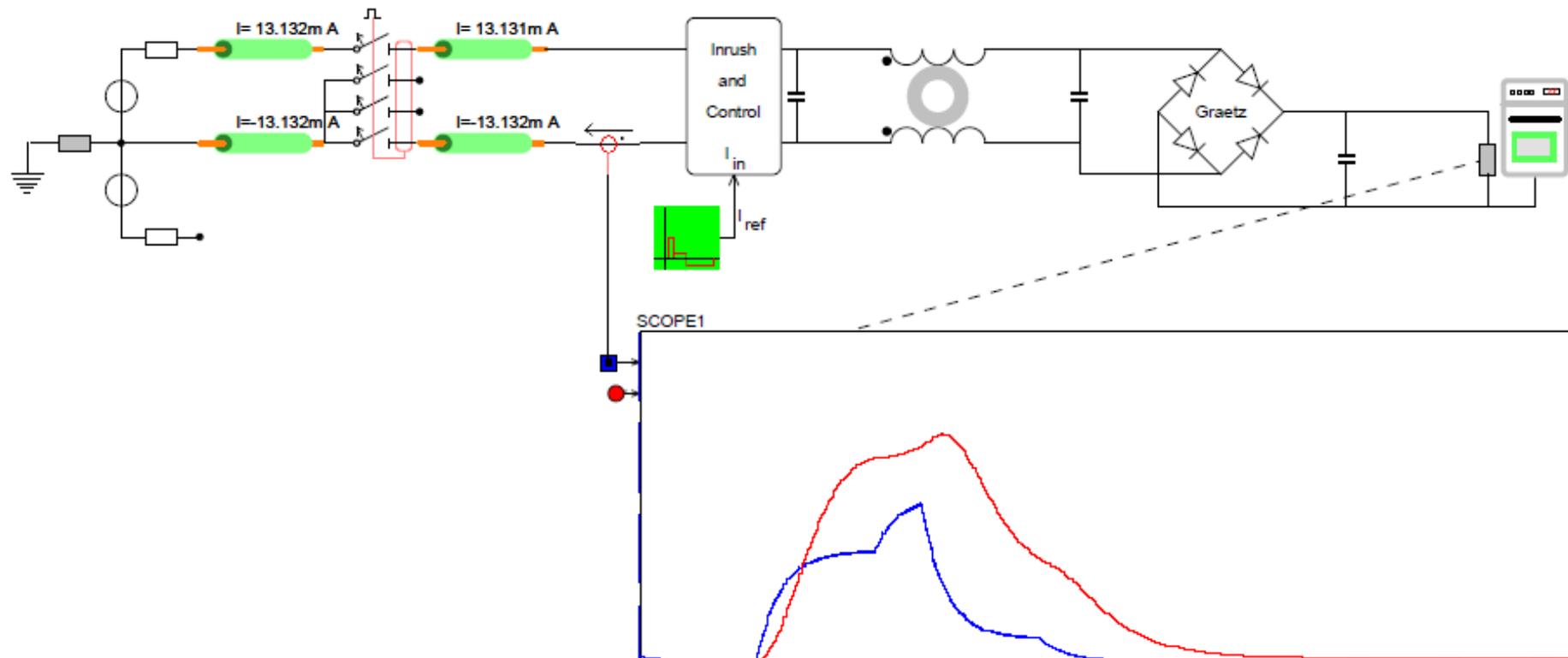
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Inrush protection using a Sepic converter

- Controlled current flow
- Input Impedance is controlled



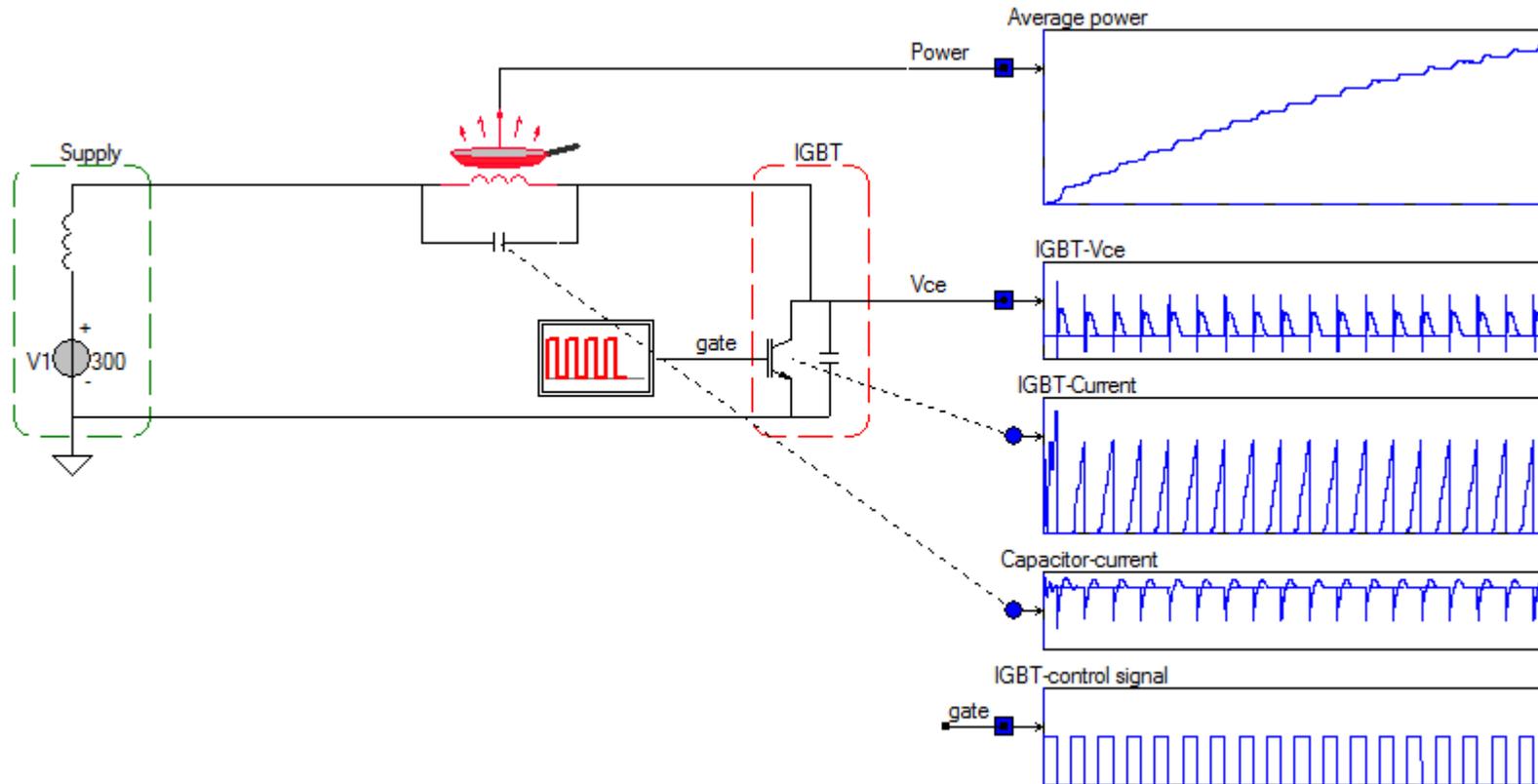
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Switching Inrush protection

Low side mosfet for inrush protection



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DC grid control?

Control and Power Congestion Management in the DC Grid



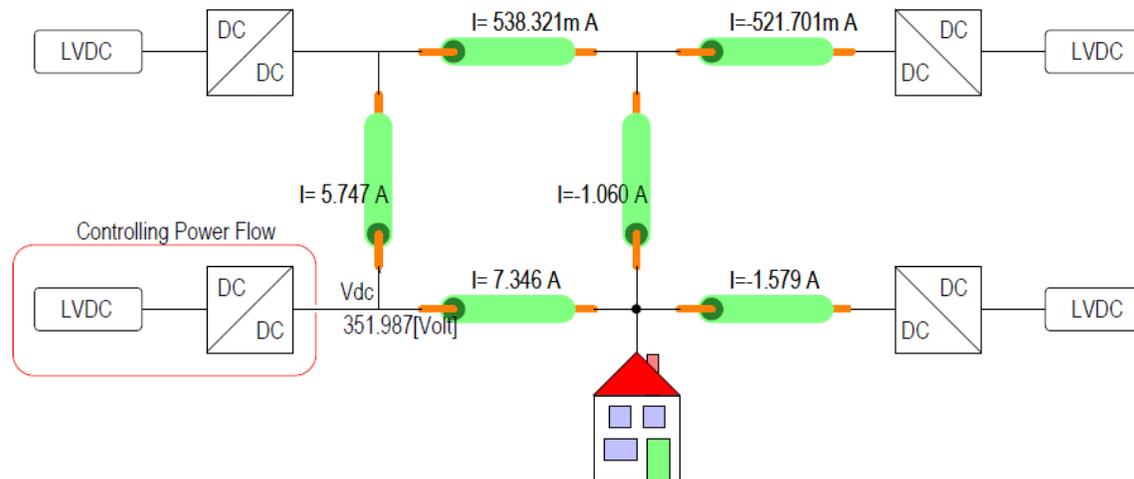
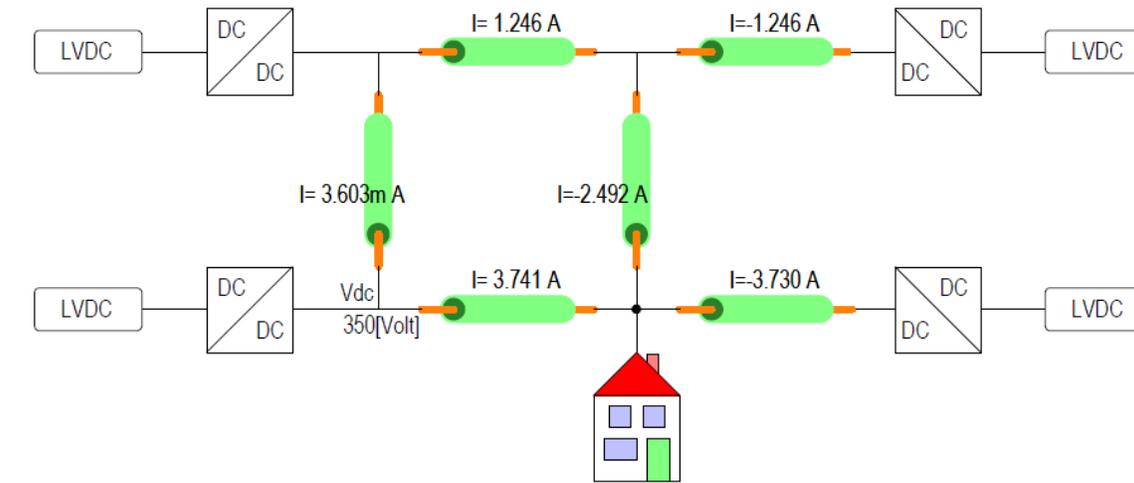
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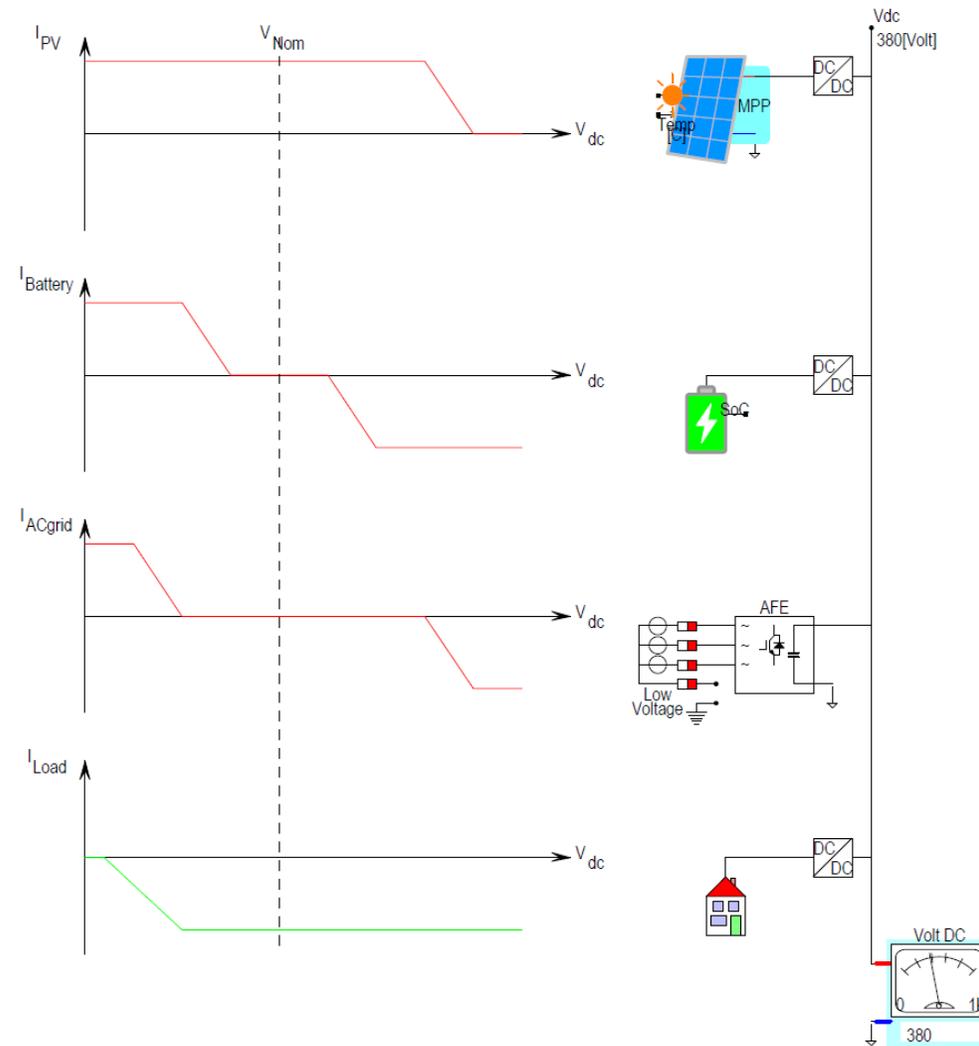
Control the current in a Meshed grid

- 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



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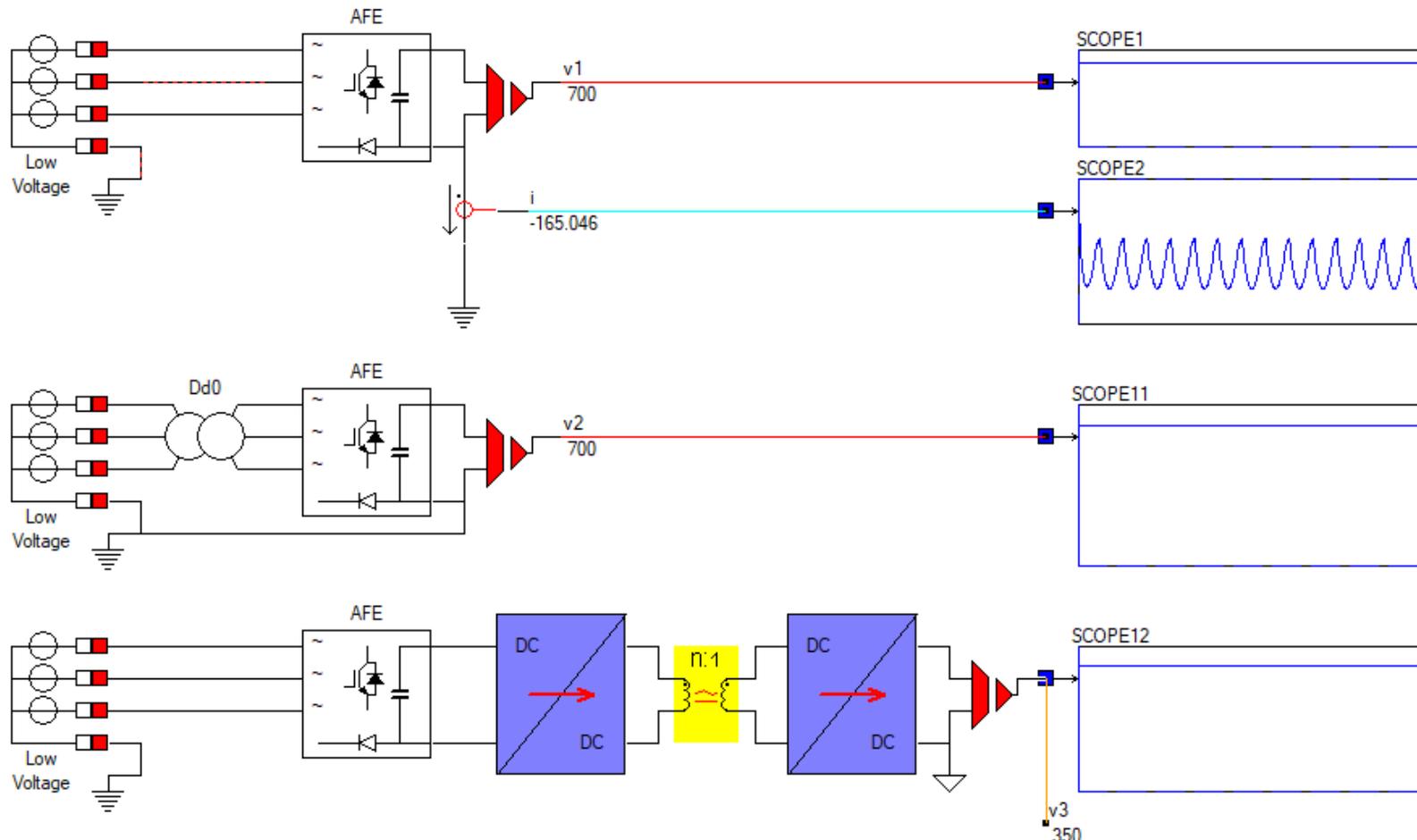
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DC grid selectivity and protection?

Protection and/or selectivity
in the DC Grid?



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

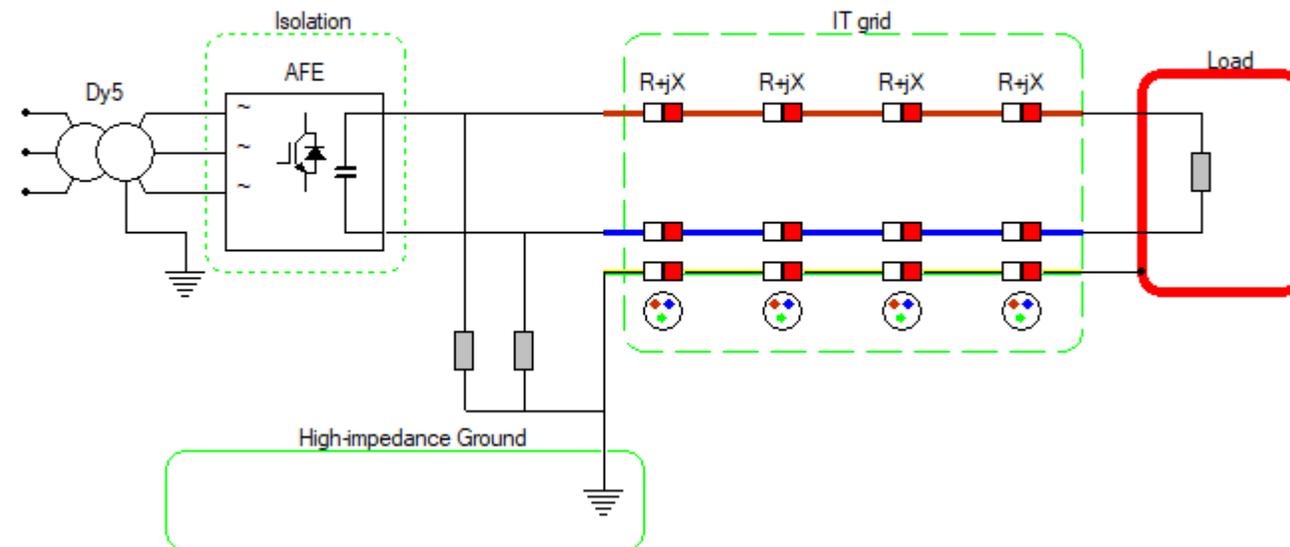


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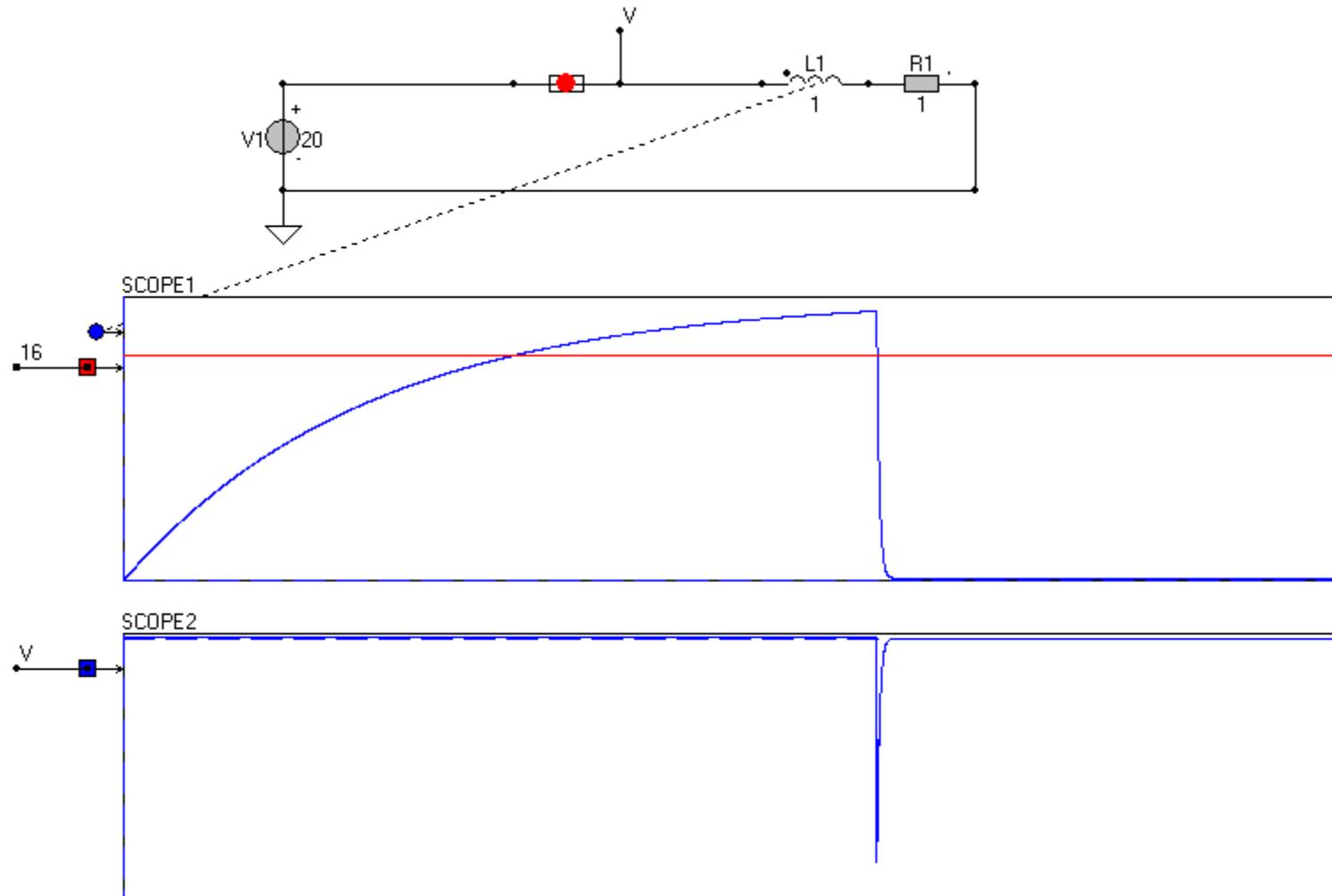
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Grid system?

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



Fuse?

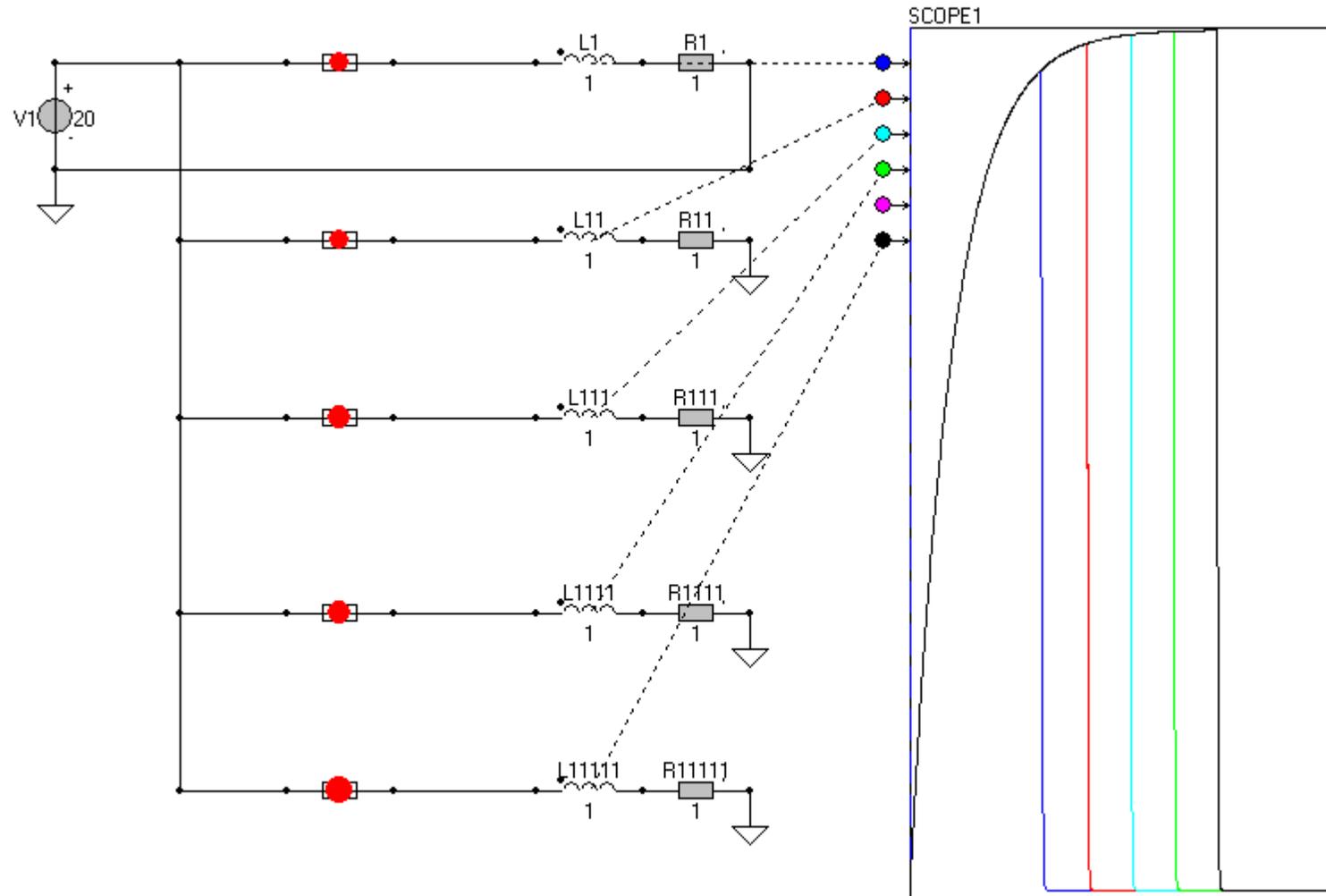


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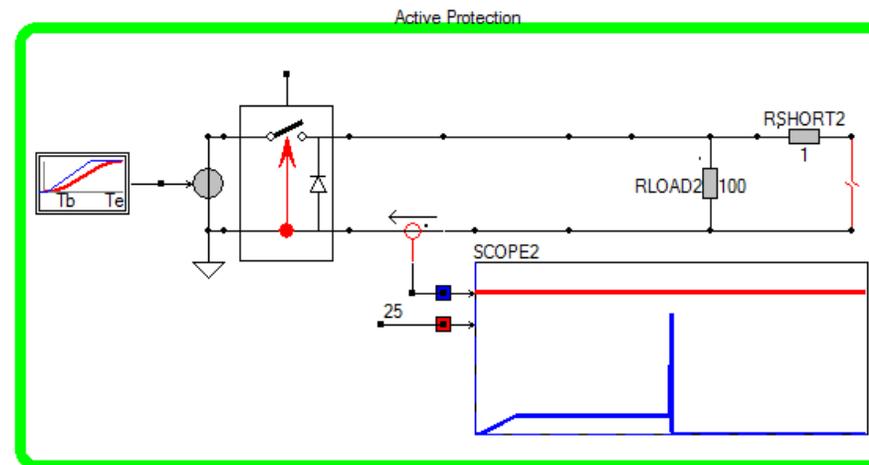
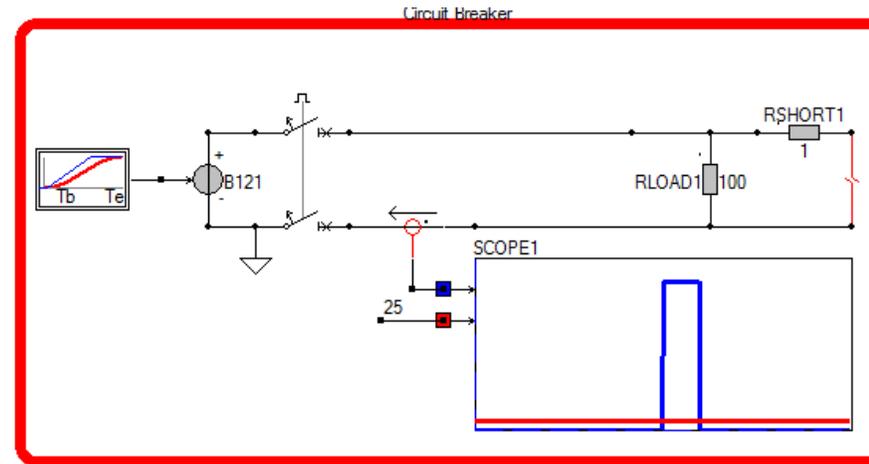
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Fuse?



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RoCoC Rate of Change of Current



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DC grid stability?

How to predict and ensure stability in the
DC Grid



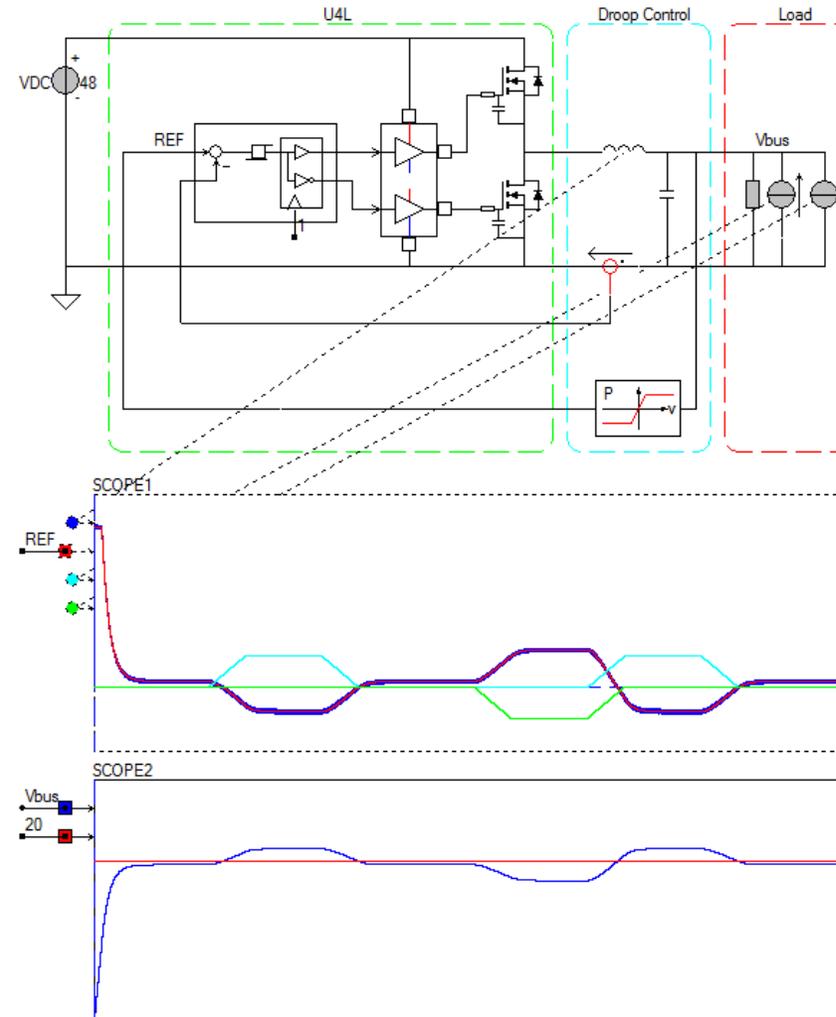
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Static stability depends in Droop Control Characteristics

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

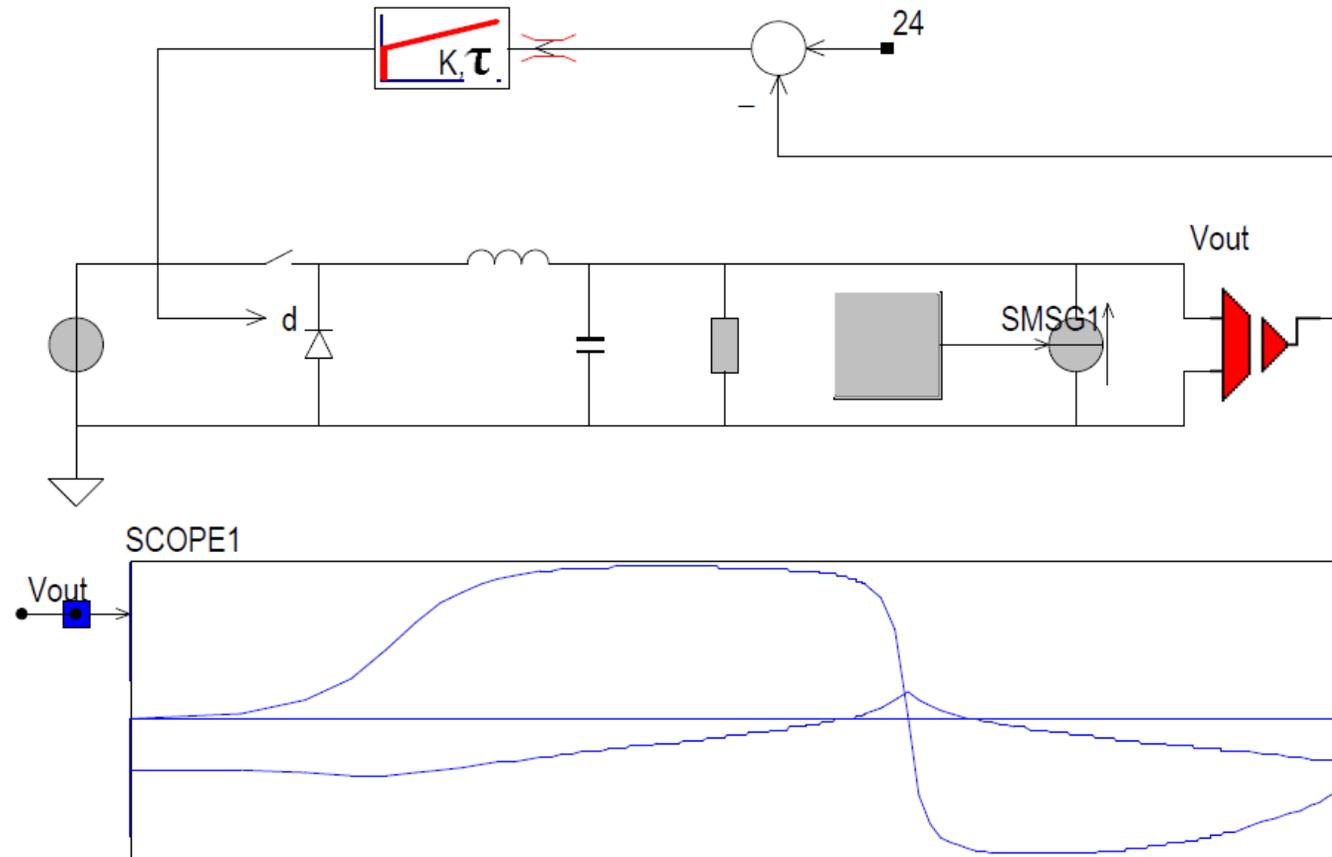


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Dynamic stability depends on input and output impedance

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



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Conclusion: DC Grid: Protect or Control?

- Centralized or Decentralized
- Control
- Protection
- Stability



Thanks for your attention!

www.dc-lab.org