DC Grids for Electric Marine, Control and Protection

Peter van Duijsen
THUAS, Delft, The Netherlands

www.dc-lab.org www.caspoc.com

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UNIVERSITY OF
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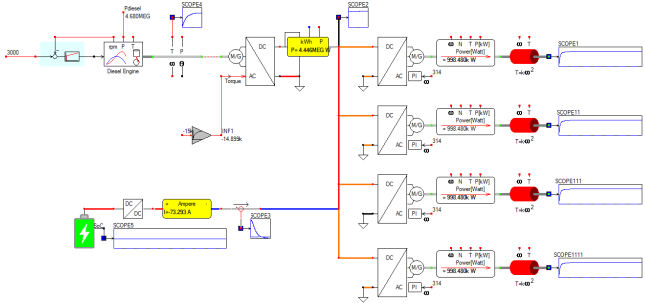
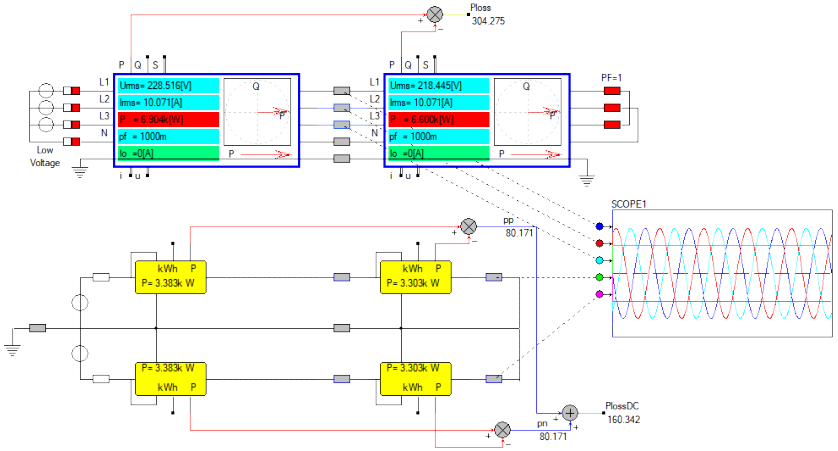


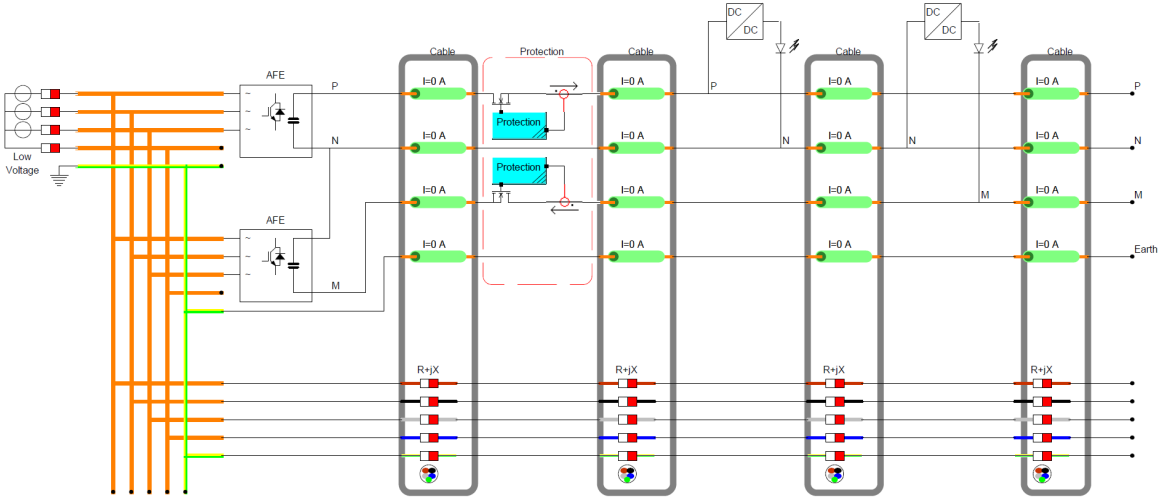
DC grid structure?

Structure of the DC Grid

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

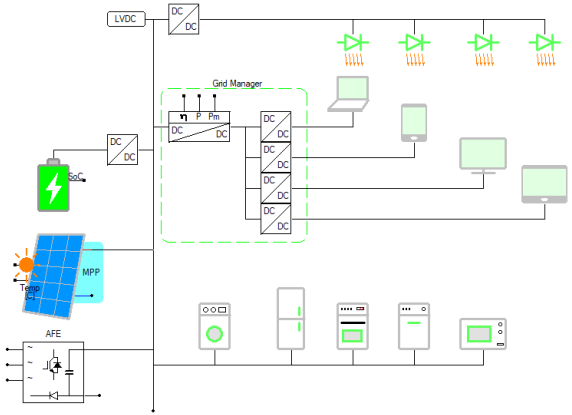


It is not about optimizing components
It is optimizing the system!



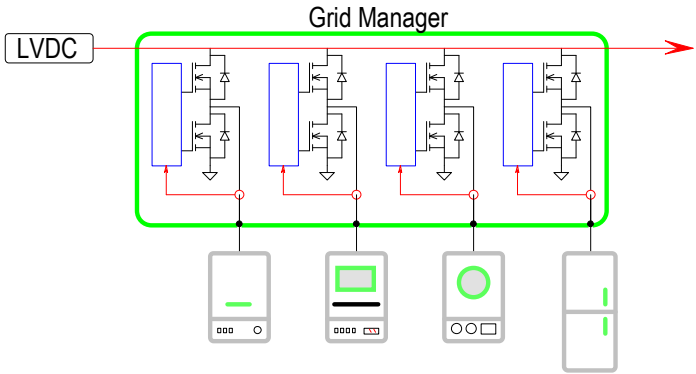
Which grid to choose?

- Centralized
- Decentralized



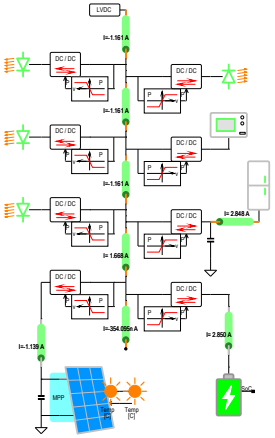
Centralized DC Grid with Grid Manager

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

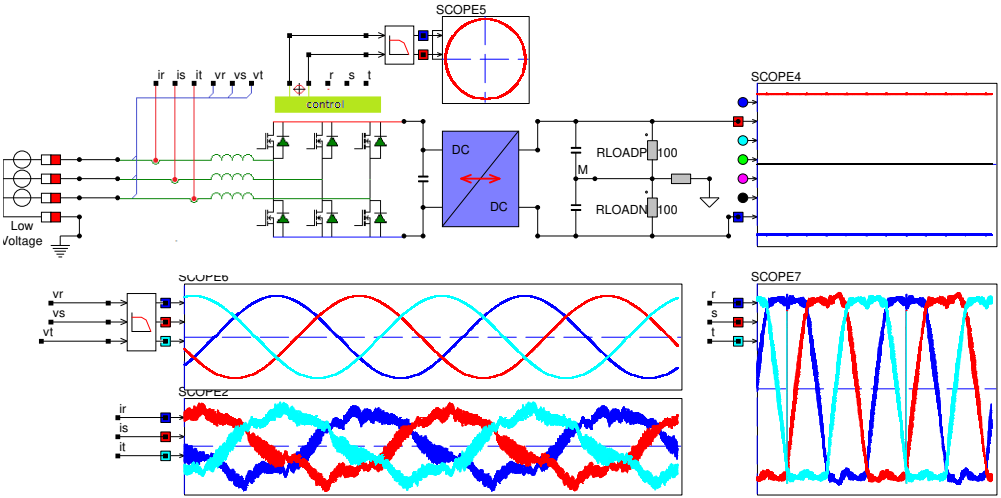


Decentralized DC Grid with Droop Control

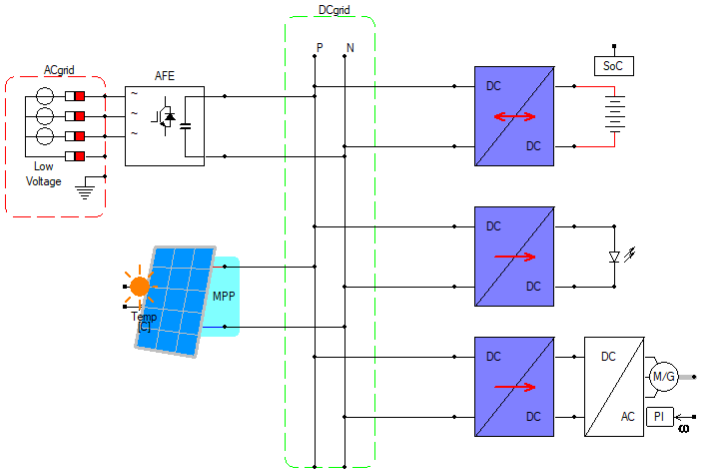
- Droop control per appliance
- DCDC converter per appliance



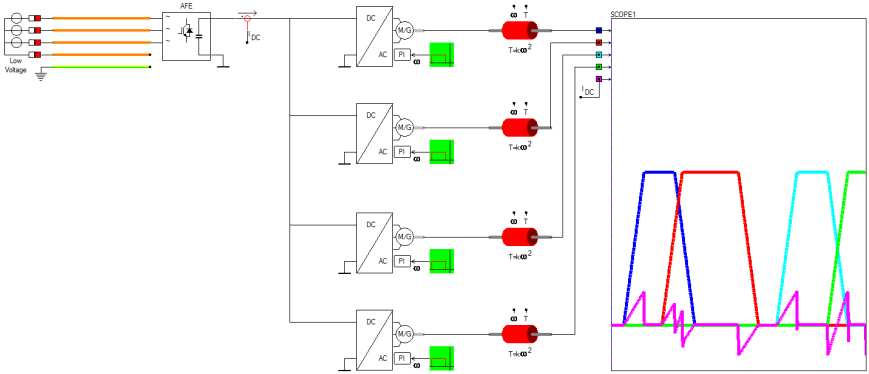
Connection to existing AC Grid?



Producers and Consumers are directly coupled



Exchange of Drive and Brake Energy

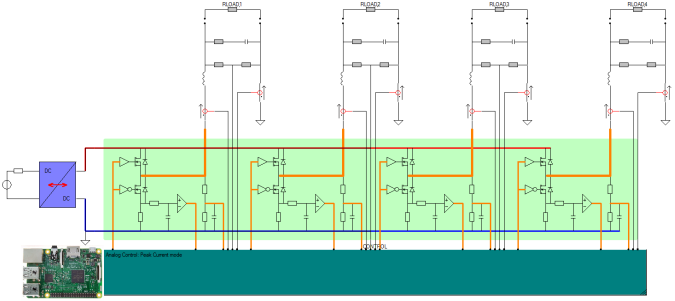


Switching in the DC grid?

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

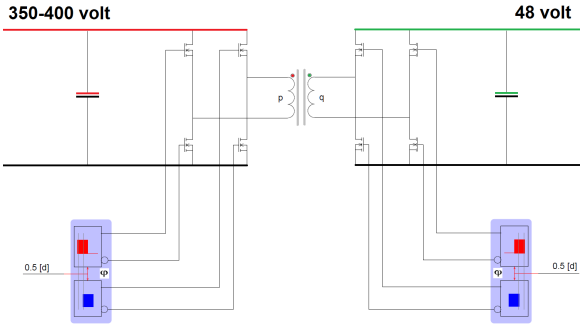
Grid Manager contains multiple Synchronous Buck Converter

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

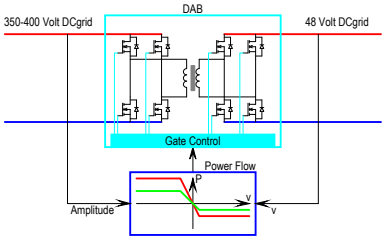


Dual Active Bridge is Isolated

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

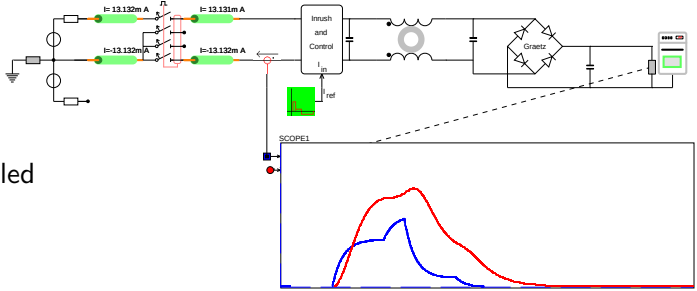


Connecting two DC grid with different voltage levels

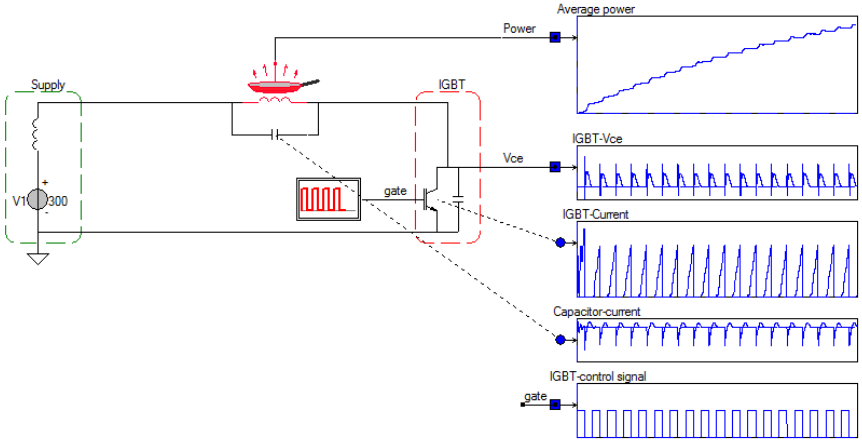


Inrush protection using a Sepic converter

- Controlled current flow
- Input Impedance is controlled



Low side mosfet for inrush protection

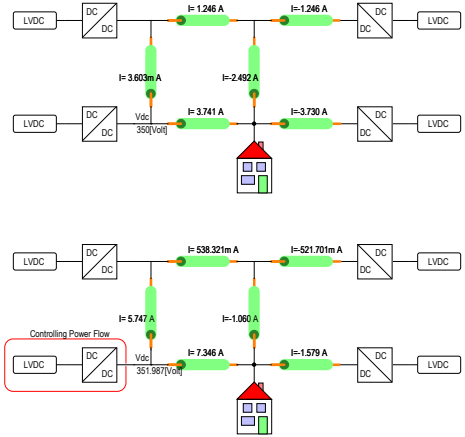


DC grid control?

Control and Power Congestion Management in the DC Grid

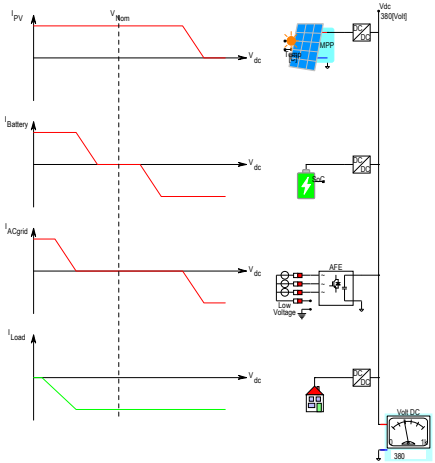
Control the current in a Meshed grid

- Nodal voltage defines current flow
- DCDC converters have losses



Droop Control regulates in a decentralized grid

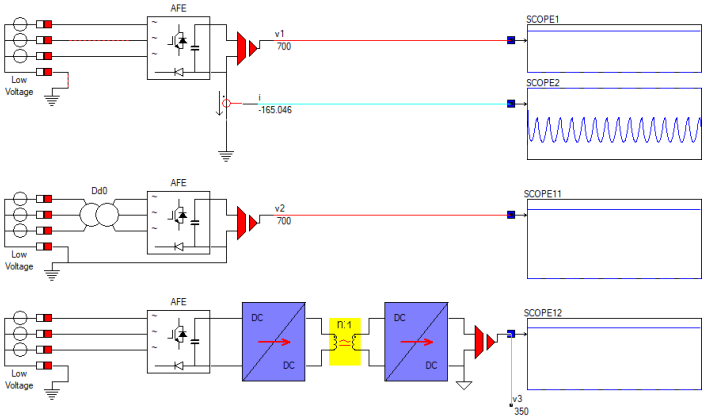
- Controlled current flow per appliance
- Islanding operation
- No communication required



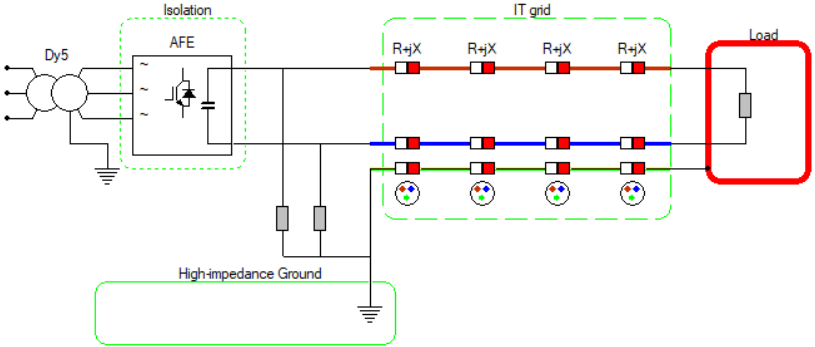
DC grid selectrivity and protection?

Protection and/or selectivity
in the DC Grid?

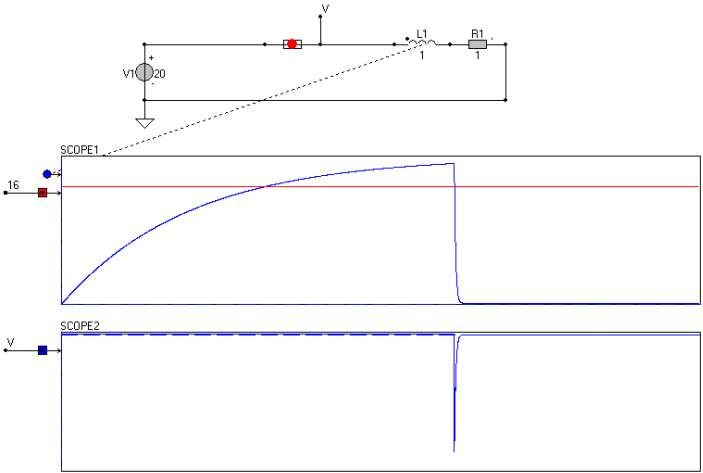
When grounding, the DC grid has to be isolated from the AC grid



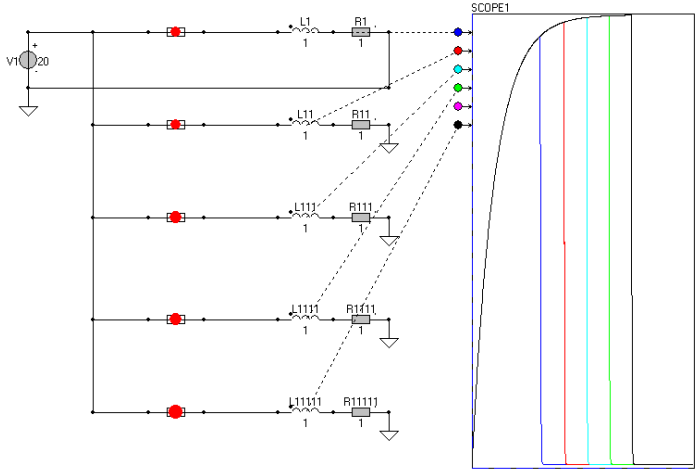
You can choose an isolated Grid **IT** to implement earth leakage detection, but your grid is floating!



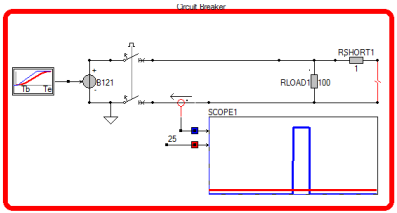
Fuse?

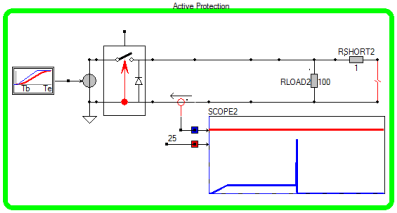


Fuse?


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



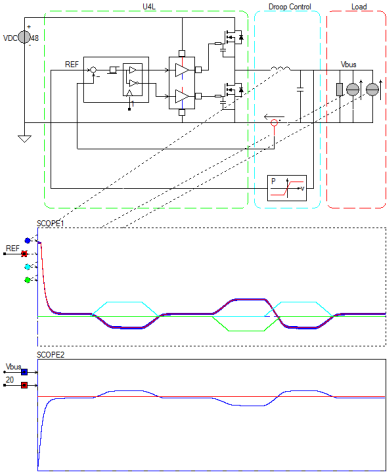


DC grid stability?

How to predict and ensure stability in the DC Grid

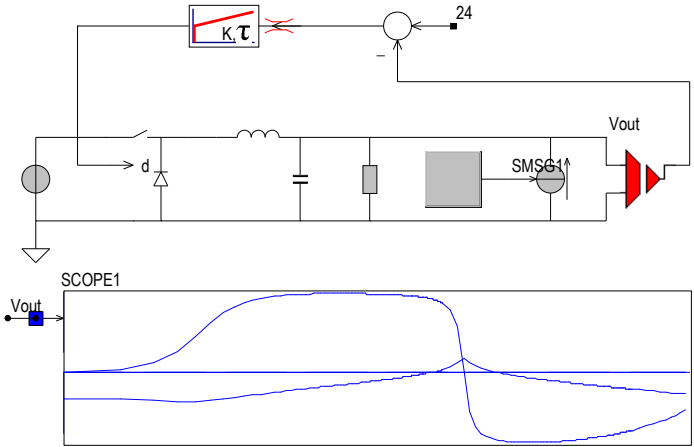
Static stability depends in Droop Control Characteristics

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



Dynamic stability depends on input and output impedance

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



DC Grid: Protect or Control?

- Centralized or Decentralized
- Control
- Protection
- Stability

Thanks for your attention!