Stability in DC Grids

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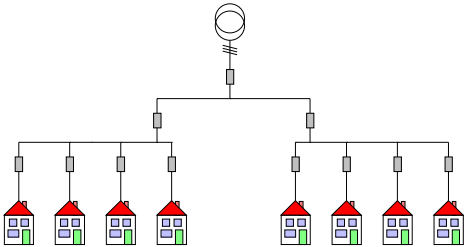
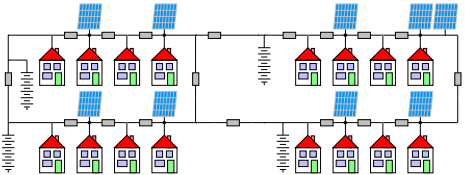
Structure

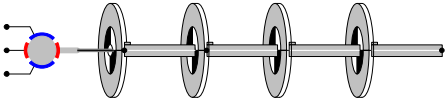
- AC Grid: Top-Down structure
  - Mostly Consumers
- DC Grid: Radial, Ring, Meshed,....
  - Prosumers

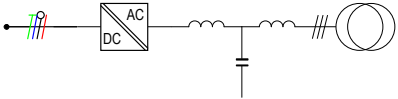




Inertia in the AC Grid

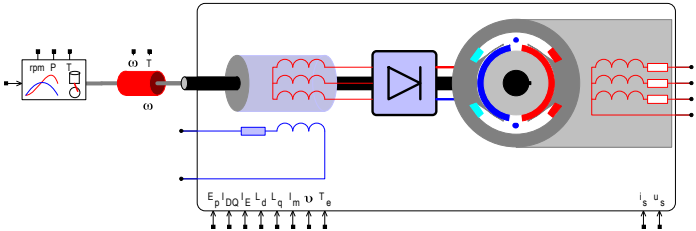
- Synchronous Generator
- Power Converter





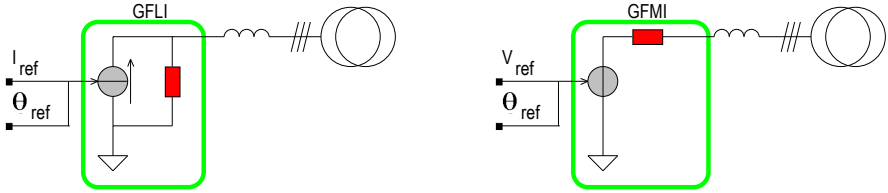
Inertia in the AC Grid

- Synchronous Generator $J = \frac{1}{2}mr^2$ = Single Large Inertia



Inertia in the AC Grid

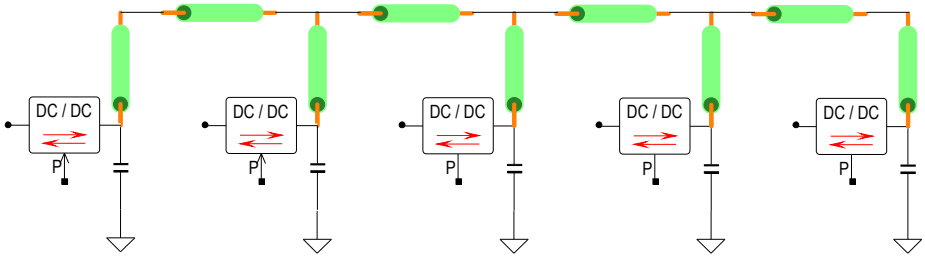
- Power Converter $\rightarrow$ No Inertia
  - Grid Following (Current Source Inverter follows AC frequency and phase)
  - Grid Forming (Voltage Source inverter with frequency droop control $\theta_{ref} = \theta_N + k_p(P_{ref} - P)$



Inertia in the DC Grid

Same problem in the DC Grid:

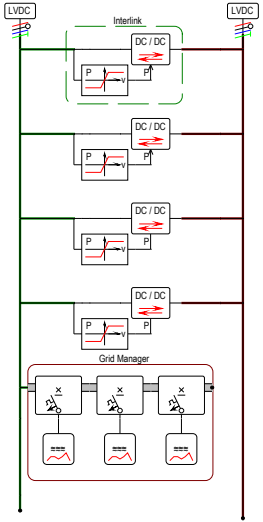
- Many Power Converters
- Many small inertia's



Main Components

Two main components:

- Interlink
  - Interface between two grids
  - Interface between Grid and Prosumer
- Grid Manager
  - Interface towards prosumers

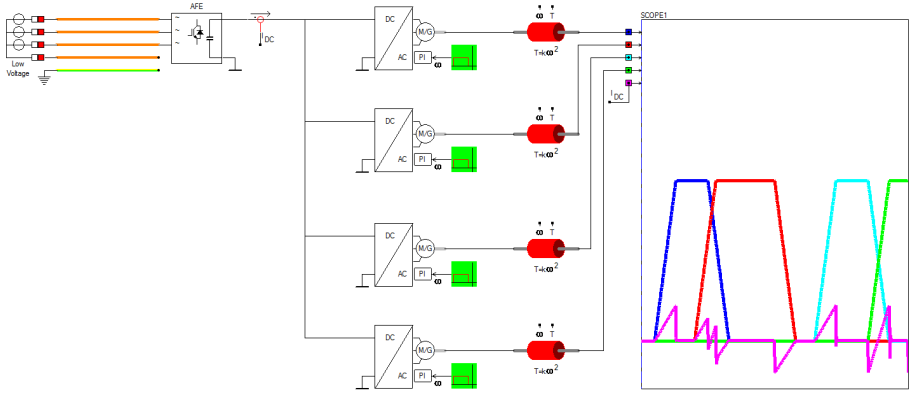


Typical Prosumers

Typical Prosumers connected via a Grid Manager or Interlink

- Solar converter + MPP
- Battery + BMS
- Inverter AC motor control
- Inverter AC Grid interface
- Inverter AC single phase Socket

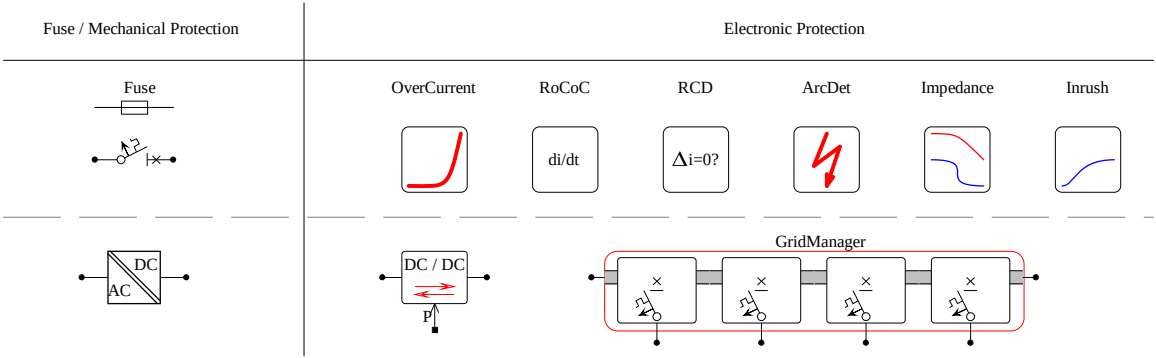
Industrial Drives



Data-center: Standard 400 volt

Protection

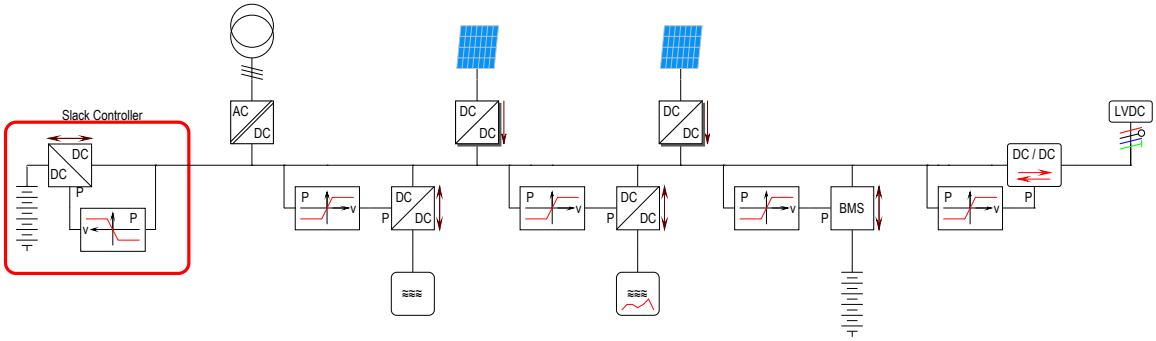
Grid Manager and Interlink contain Protection



Slack Controller

Slack controller that regulates the voltage level is required.

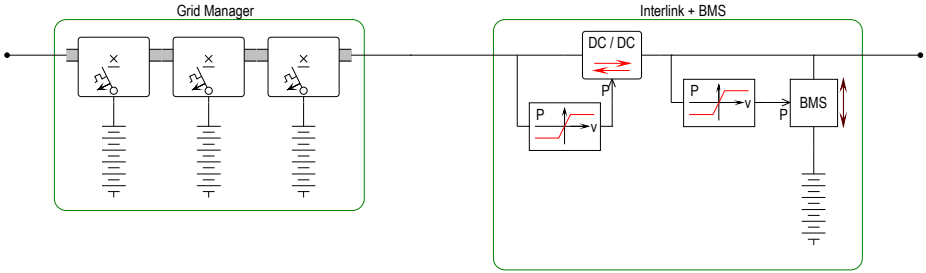
- Injects/Absorbs energy from the DC Grid to maintain the voltage level
  - Droop Control (Preferred)
  - Hierarchical Control
- Requires Storage



Slack Controller Converter

Slack controller is typically

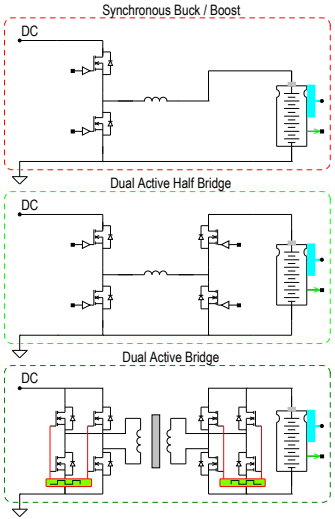
- Grid Manager + Battery
- Interlink + Battery



Power Electronics Converters

Interface to Battery

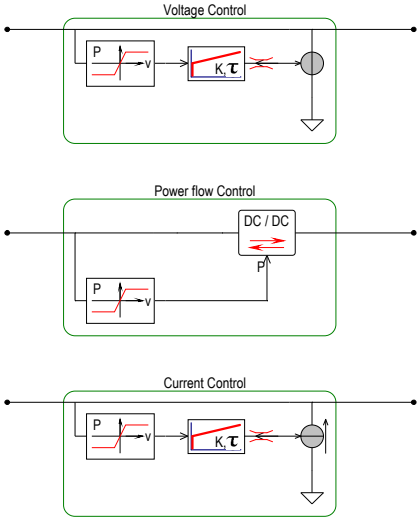
- Synchronous Buck
- DAHB
- DAB



Large Signal Stability

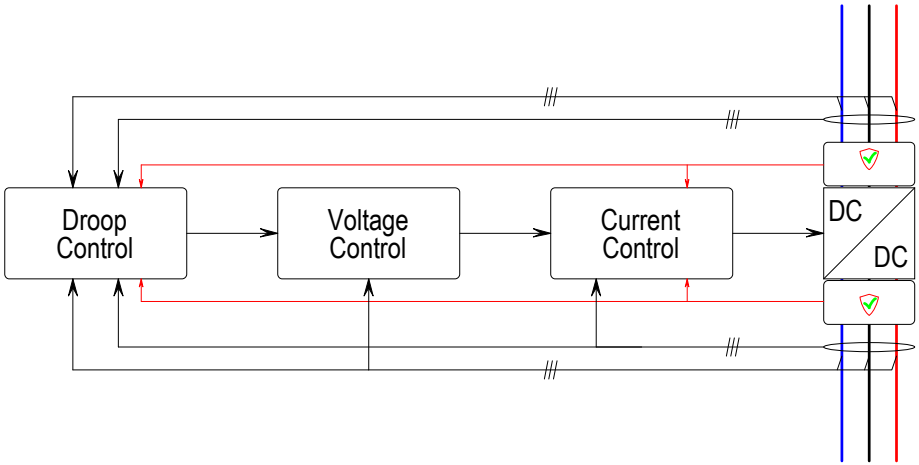
Droop control regulates

- Output voltage
- Bidirectional power flow
- Input or output current



Small Signal Stability

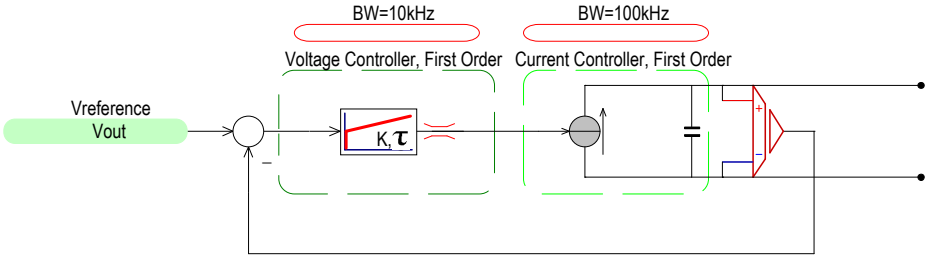
Small Signal Stability Analysis: Bandwidth (s, ms, μs)



Order reduction in Power Electronics

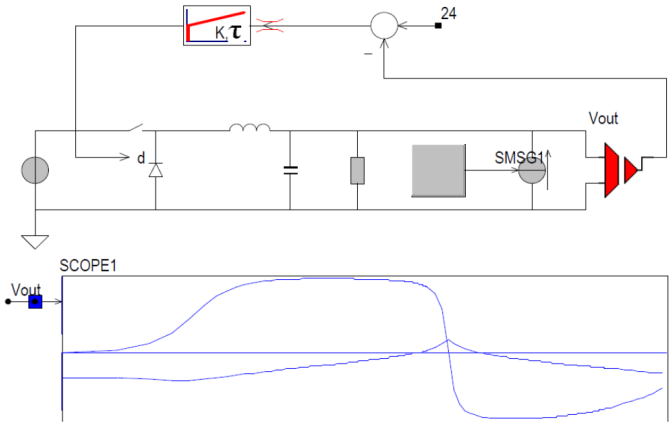
Discontinuous operation or Current Mode Control reduces the order of the transfer functions
Converter becomes a controlled current source with parallel capacitor

- Boost converter in discontinuous mode → first order model
- Synchronous Buck in discontinuous mode → first order model
- Buck and/or Boost with current mode control → first order model
- DAB with Phase Shift control → first order model



Small Signal Stability

Small Signal Stability Analysis: Bode Plot → Output Impedance, measured in Caspoc

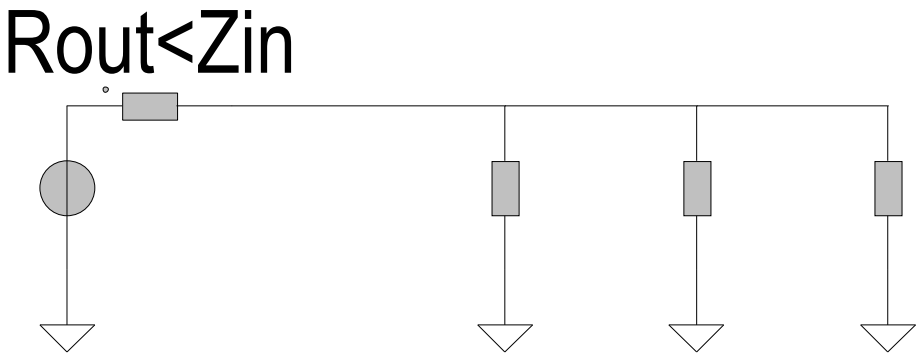


Small Signal Stability

Middlebrook Stability Criteria

$$Z_{out}^{Converter} < Z_{in}^{DCgrid}$$

for every frequency.....



Conclusion

- Inertia AC >> Inertia DC
- AC:Consumers & DC:Prosumers
- Grid Manager & Interlink & Protection
- Large signal stability: Slack Controller
- Small Signal Stability: $Z_{out} << Z_{in}$

Thank you!
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