Structuring, Controlling and Protecting the DC Grid

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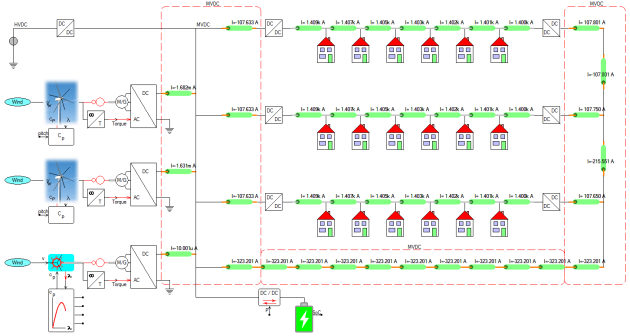
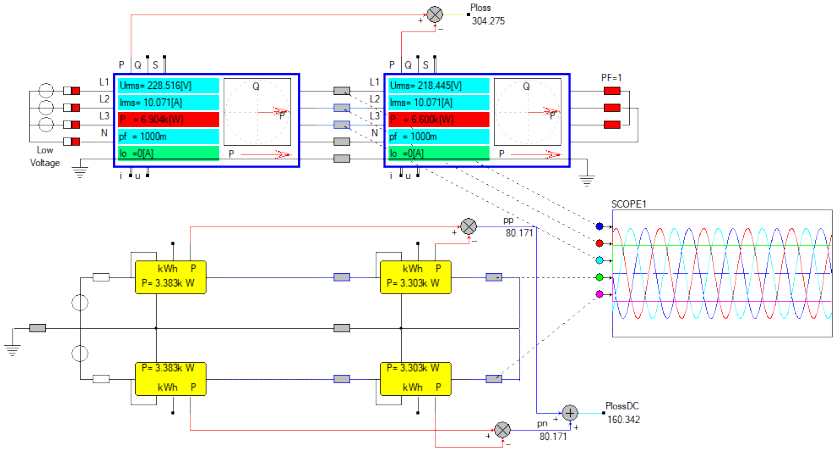


DC grid structure?

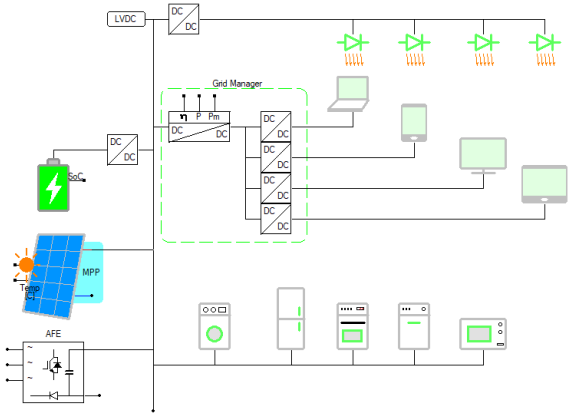
Structure of the DC Grid

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



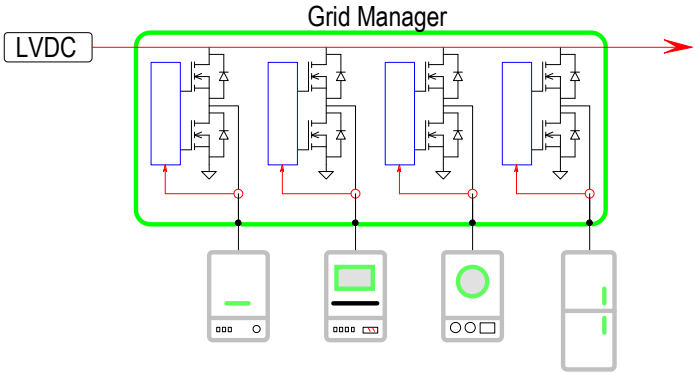
Which grid to choose?

- Centralized
- Decentralized



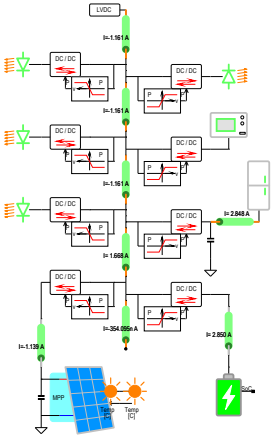
Centralized DC Grid with Grid Manager

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

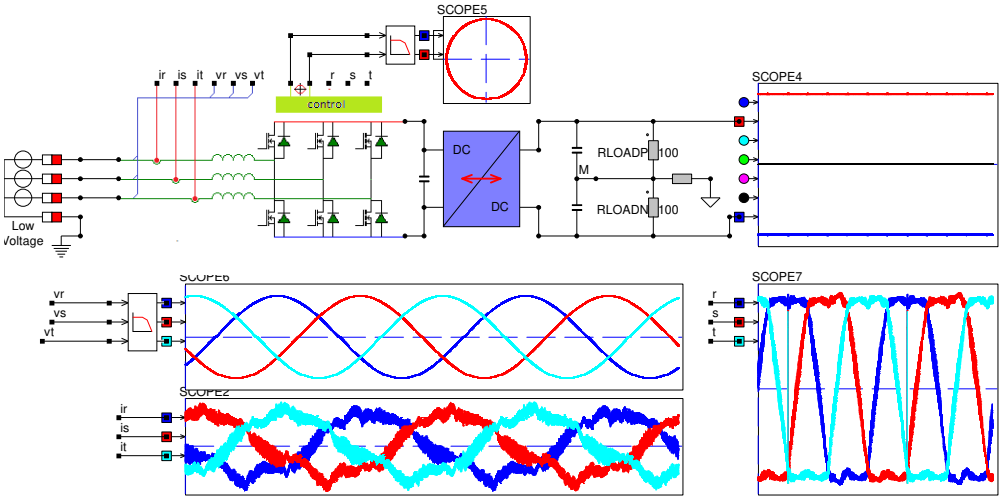


Decentralized DC Grid with Droop Control

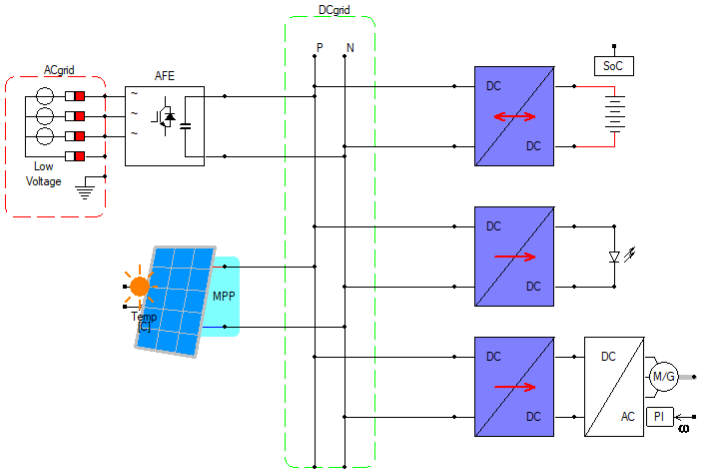
- Droop control per appliance
- DCDC converter per appliance



Connection to existing AC Grid?



Producers and Consumers are directly coupled

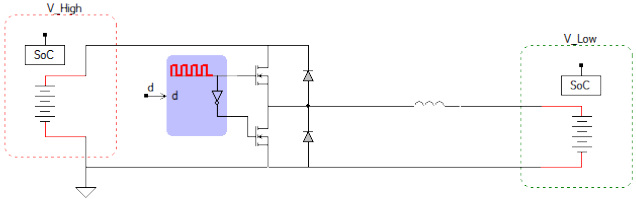


Switching in the DC grid?

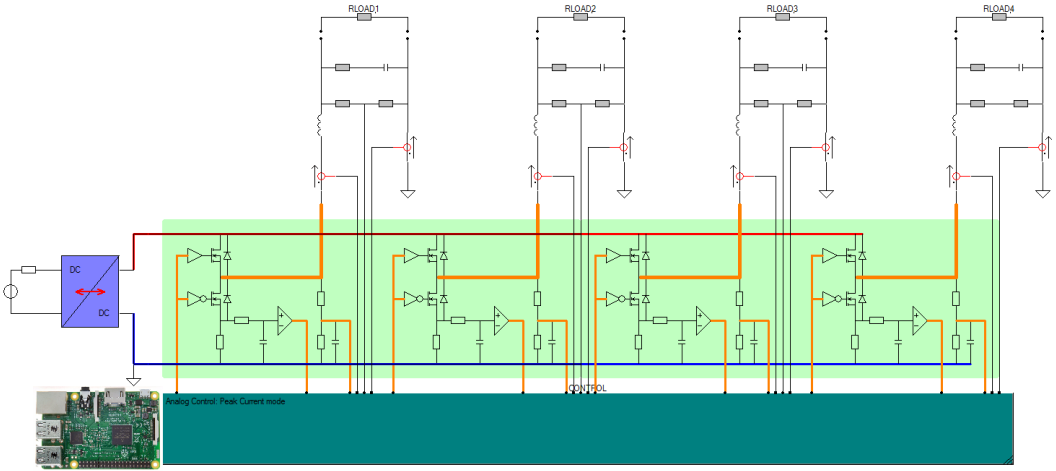
What type of switches do exist,
if they do exist at all?

Grid Manager is essentially a Synchronous Buck Converter

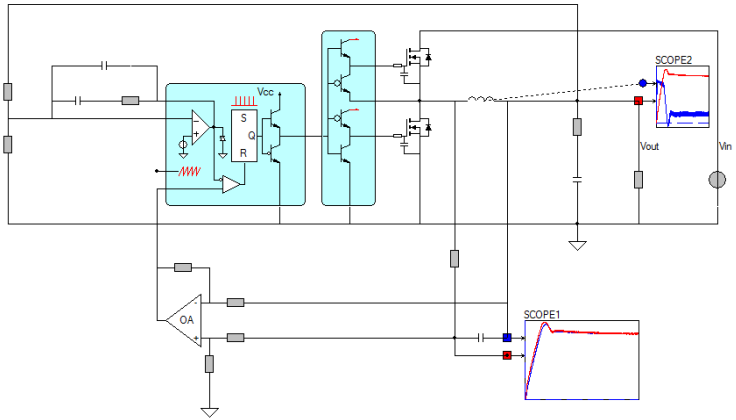
- power flow
- Current Limited
- Breaker
- Non-Isolated



Grid Manager contains multiple Synchronous Buck converters

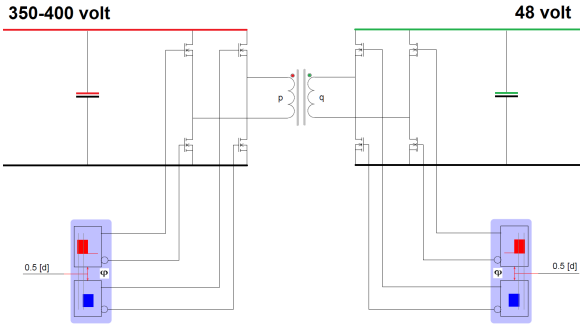


LSD
Basics of the Grid Manager, essentially a buck or boost

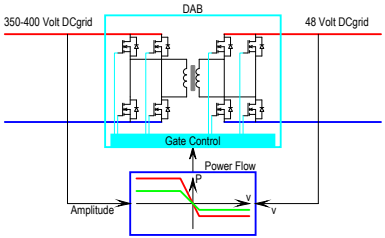


Dual Active Bridge is Isolated

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

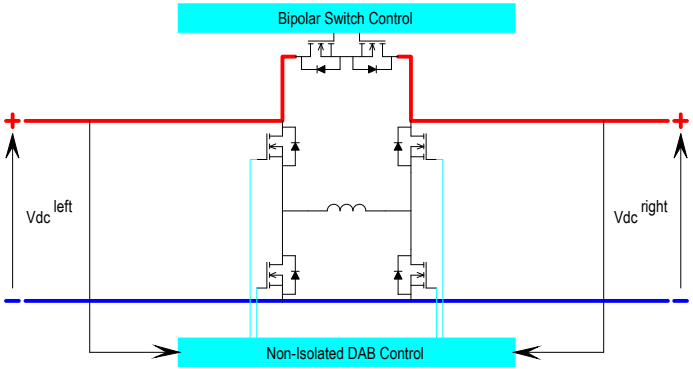


Connecting two DC grid with different voltage levels

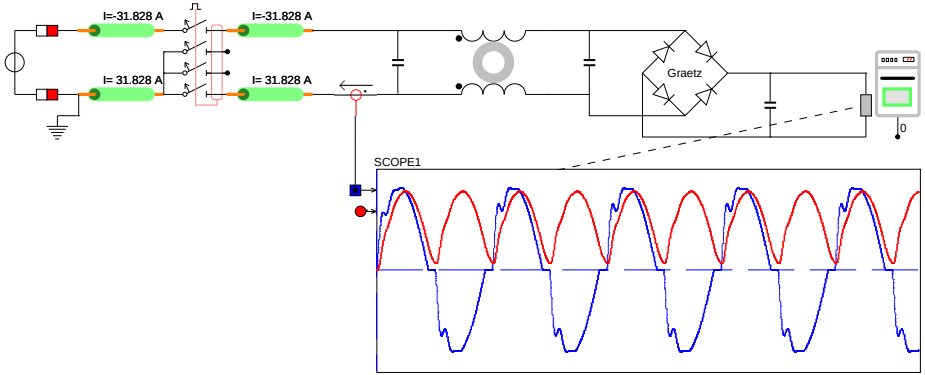


Dual Active Bridge with Bidirectional Switch

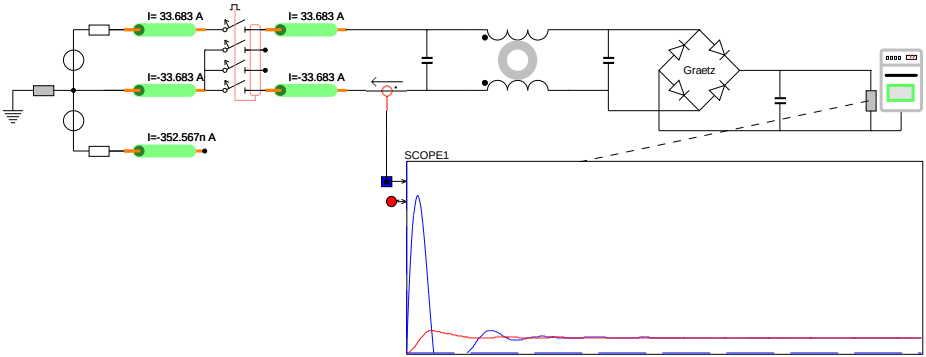
- Bidirectional power flow
- Current Limited
- Breaker
- Non-Isolated
- Minimizes Losses



In AC there is nearly inrush because of the high AC impedance

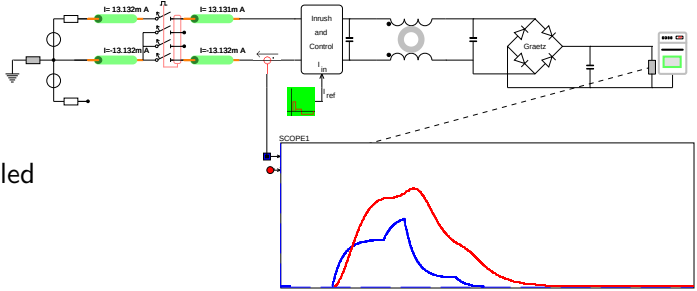


An AC appliance connected to a DC grid has a high inrush current, therefore an inrush limiter is required

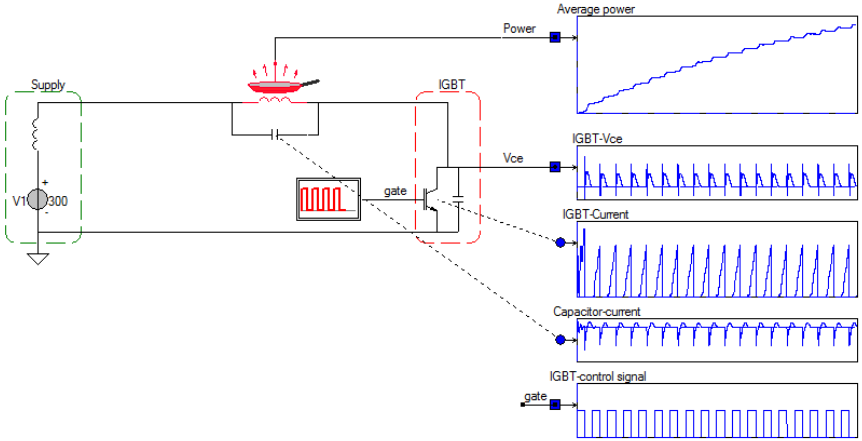


Inrush protection using a Sepic converter

- Controlled current flow
- Input Impedance is controlled

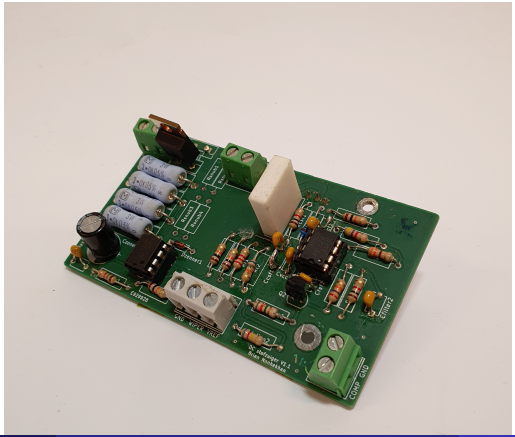


Low side mosfet for inrush protection



Current controller for Vacuum Cleaner

Speed control and limited inrush current for a classical Universal brushed motor connected to a 350 Volt DC grid.

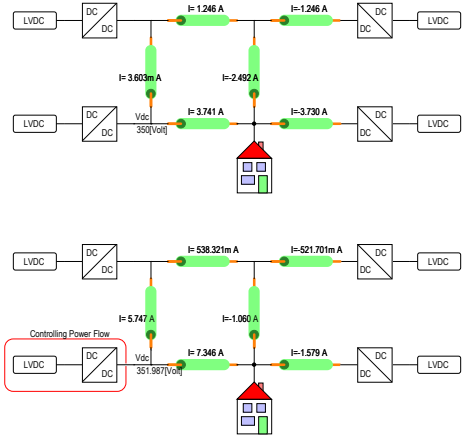


DC grid control?

Control and Power Congestion Management in the DC Grid

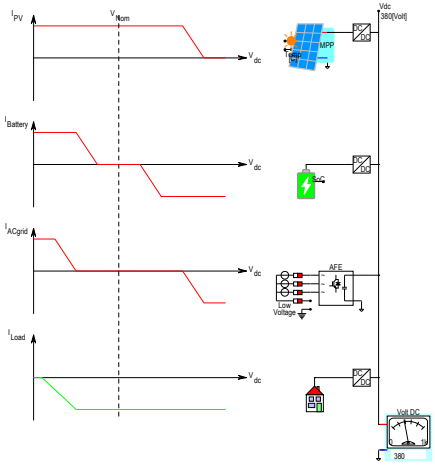
Control the current in a Meshed grid

- Nodal voltage defines current flow
- DCDC converters have losses



Droop Control regulates in a decentralized grid

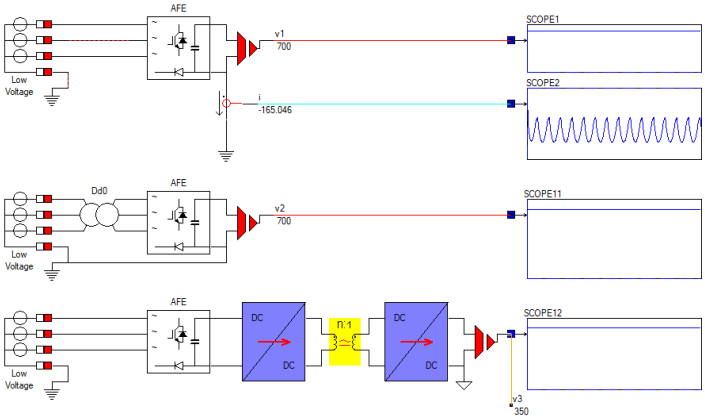
- Controlled current flow per appliance
- Islanding operation
- No communication required



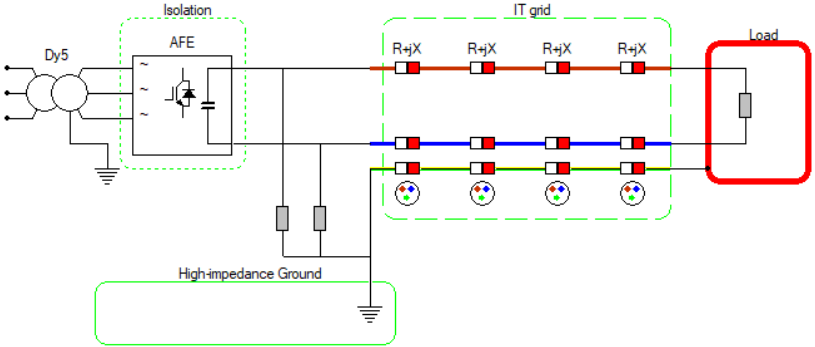
DC grid selectrivity and protection?

Protection and/or selectivity
in the DC Grid?

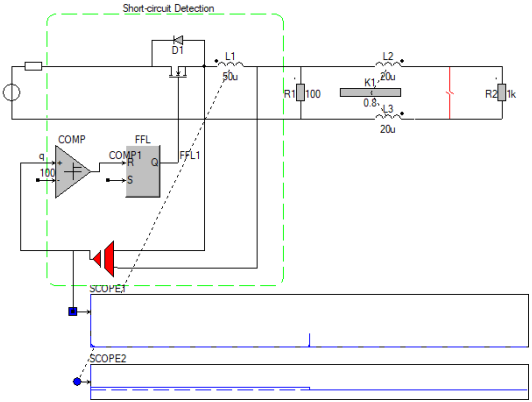
When grounding, the DC grid has to be isolated from the AC grid



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



RoCoC Rate of Change of Current

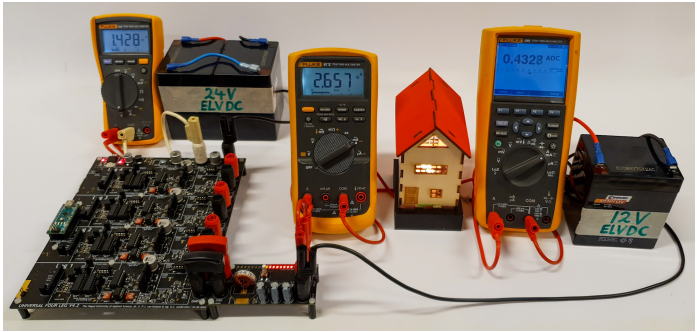


DC grid stability?

How to predict and ensure stability in the DC Grid

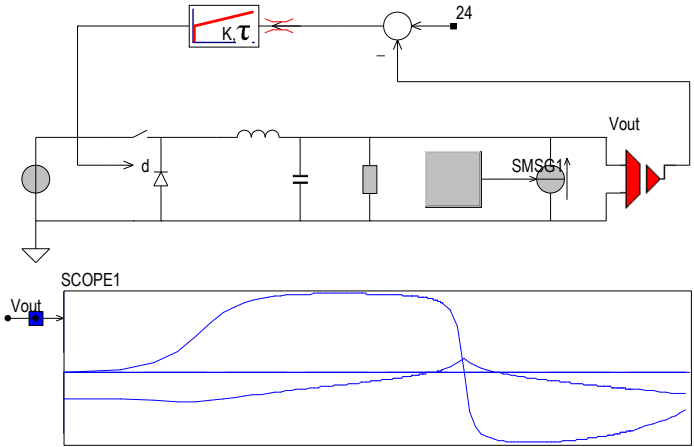
Static stability depends in Droop Control Characteristics

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



Dynamic stability depends on input and output impedance

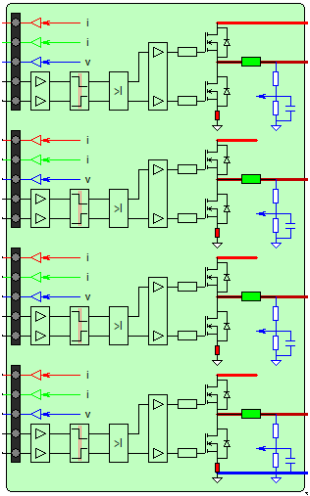
- $Z_{out} < Z_{in}$
- Middlebrooks Stability Criterion



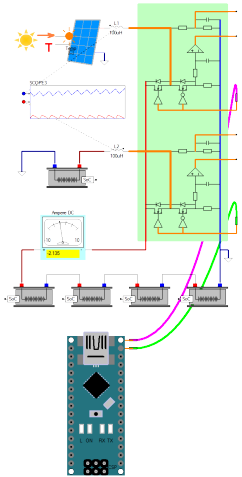
DC grid appliances

Typical examples of DC grid appliances

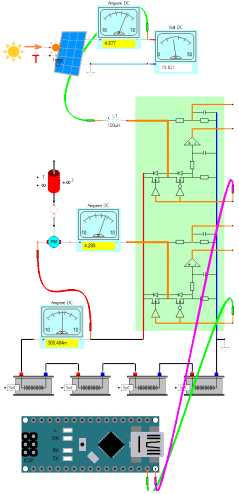
Educational setup building a DC Grid Manager



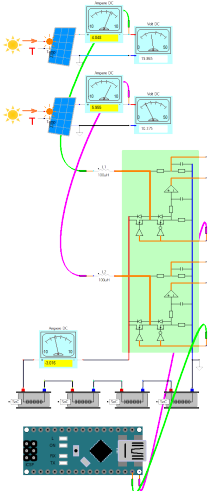
Battery charging from a Solar Panel



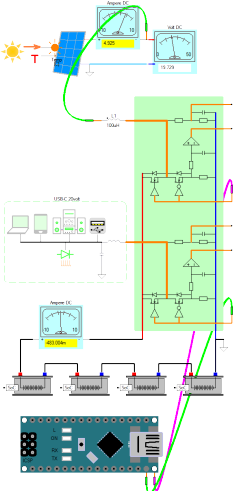
Power tools connected to a DC Grid



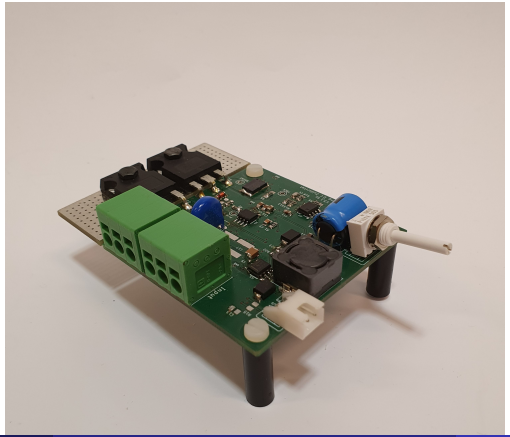
Multiple Solar panels with individual MPP controllers



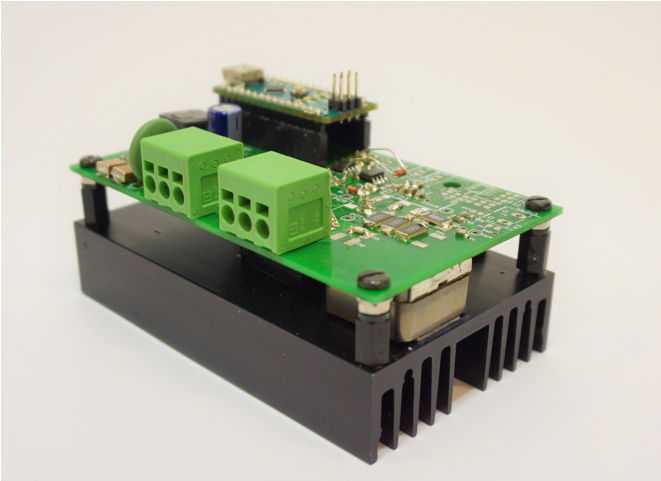
Feeding USB-C devices from Solar



Controller single phase AC loads in a DC grid.
Current control and limiting inrush current for a single phase loads connected to a 350 Volt DC grid.

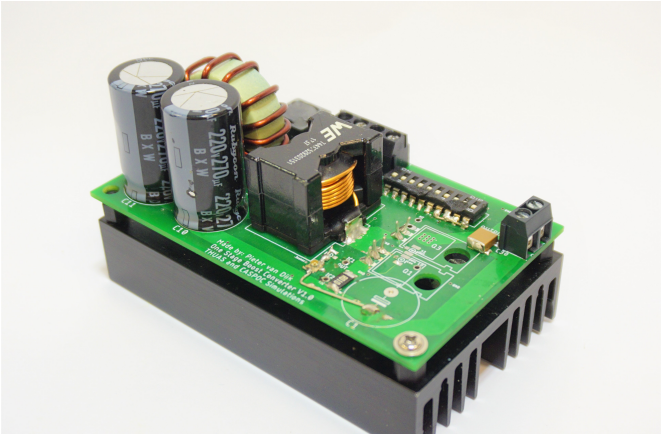


Current limiter for dc and single phase AC loads.
Limiting inrush current for loads connected to a 350 Volt DC grid.

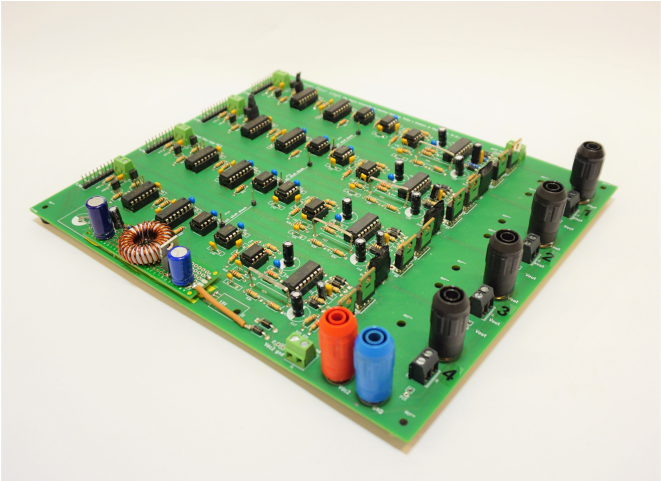


Boost converter.

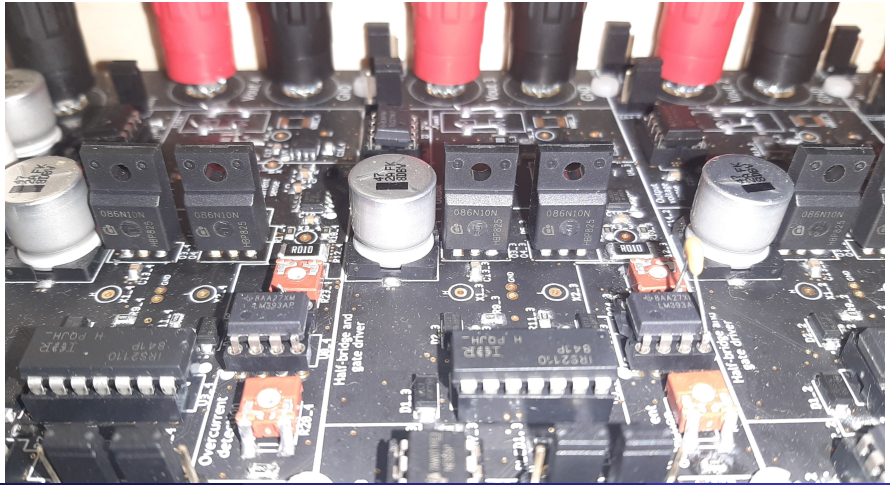
First stage out of two stages in a Boost converter, converting 48volt via 110 volt to 400volt.



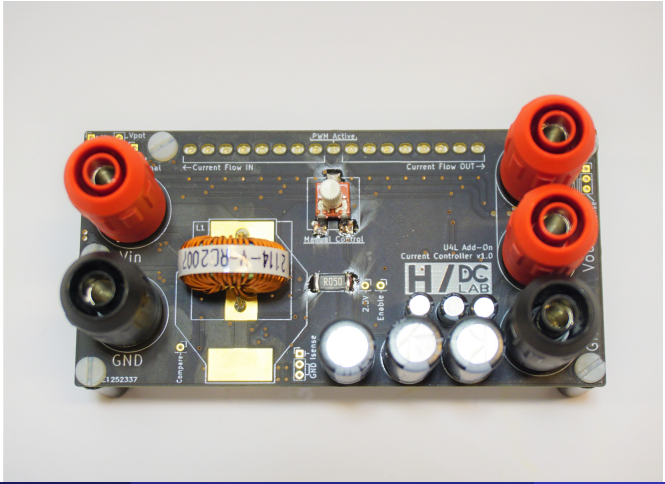
Prototype of the Universal Four Leg: U4L.
Picture courtesy of the DC-lab Heritage.



Universal Four Leg: U4L.
Grid Manager for 48 volt DC grids, 4 outputs.



Droop control add on to the U4L.
Contains analog controller and high bandwidth current measurement.



DC Grid: Protect or Control?

- Centralized or Decentralized
- Control
- Protection
- Stability

Mulțumesc!

Questions?

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