Voltage Dips and Converter-Connected Distributed Generation Units

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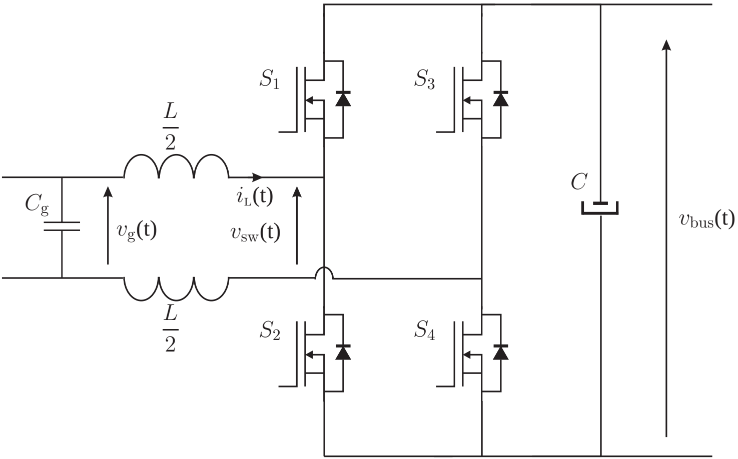
Overview

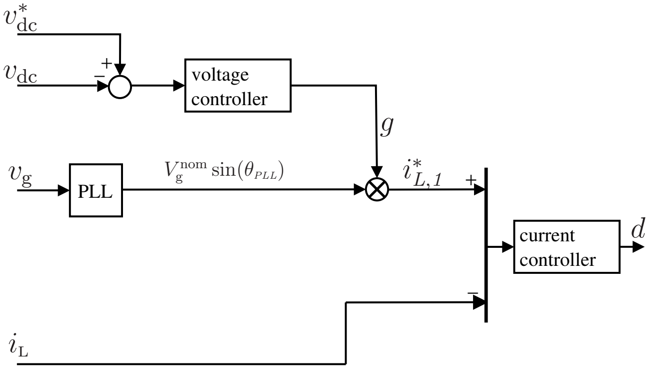
1. Converter-Connected DG units
   - Full-Bridge Converter
   - Control Strategy
2. Voltage Dip Ride-Through Capability
   - Instantaneous Reaction
   - Bus Voltage
3. Retained Voltage
4. Conclusions

Full-Bridge Converter

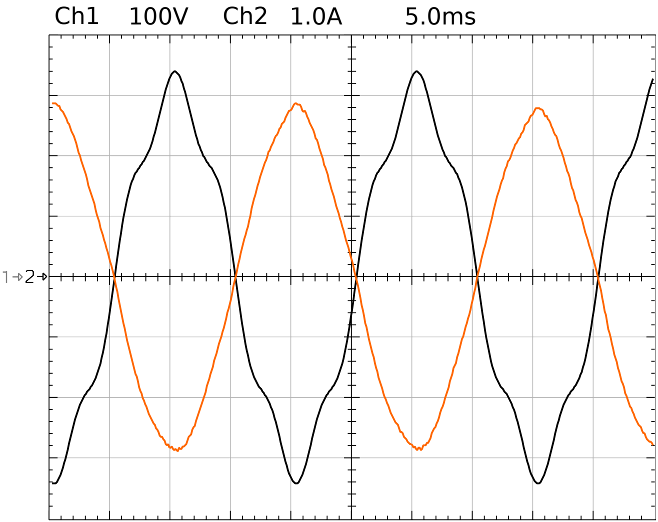


Topology of the active front-end of the DG unit

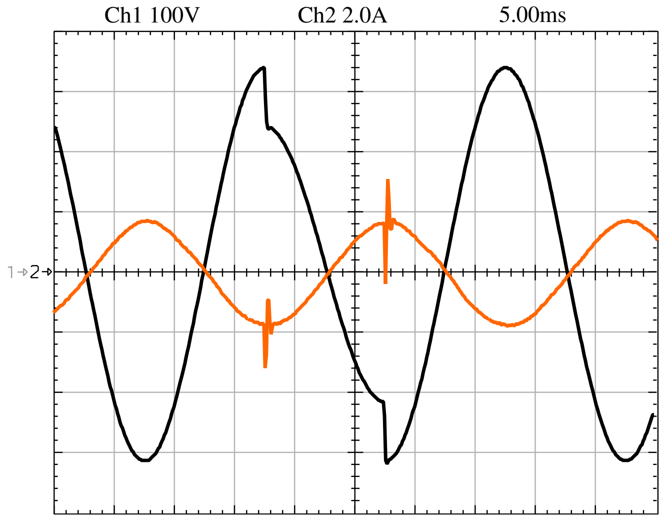
Control Strategy



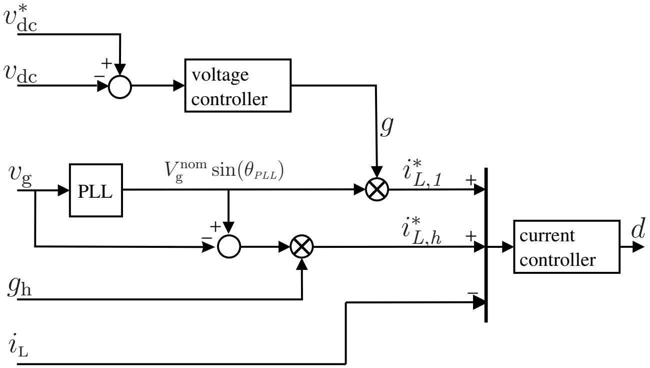
Control Strategy



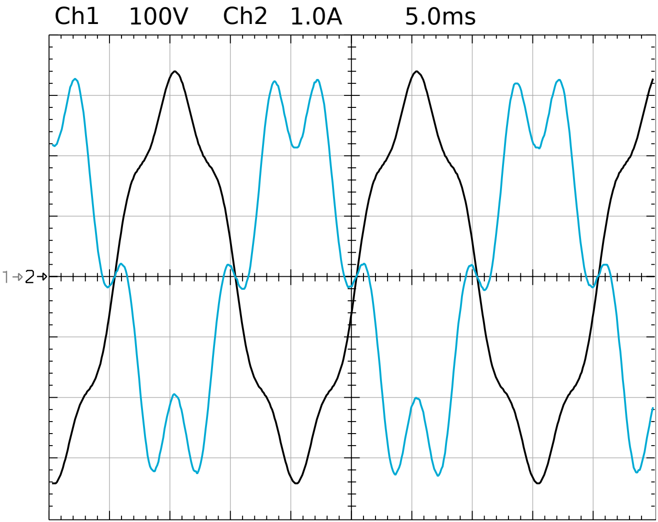
Control Strategy



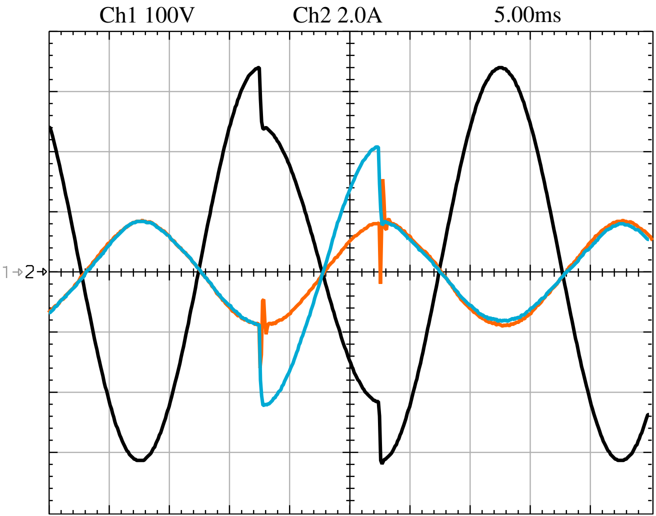
Control Strategy



Control Strategy



Control Strategy



Overview

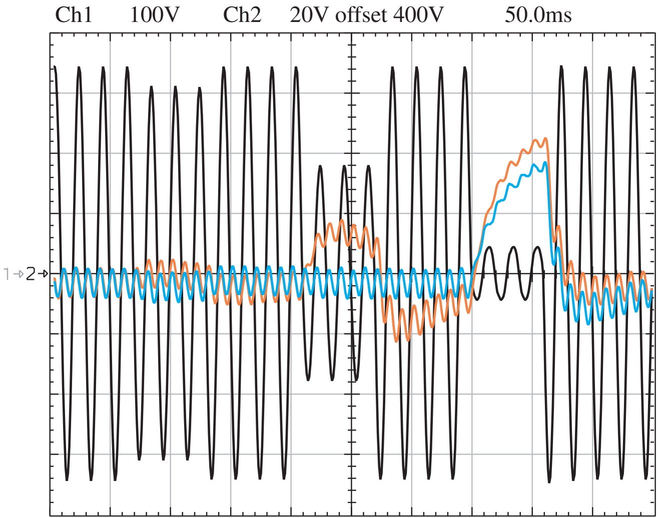
Instantaneous Reaction

- Before dip initiation: $P_{\mathrm{dc}} = P_{\mathrm{ac}}$
  - P_{dc} Power delivered by the DG-unit
  - P_{ac} Power injected by the converter into the utility grid
- At dip initiation: $P_{\mathrm{dc}} \neq P_{\mathrm{ac}}$
  - Power excess is absorbed in the bus capacitor
  - Bus voltage variation
- Main reason for shutdown: excessive bus voltage
- Experimental results:
  $i_{\mathrm{L}} \approx g \sin(\theta_{\mathrm{PLL}}) + g_{\mathrm{h}} \left(v_{\mathrm{g}} - \sin(\theta_{\mathrm{PLL}})\right)$
  - P_{ac} is higher as compared to the 'classical' control strategy.

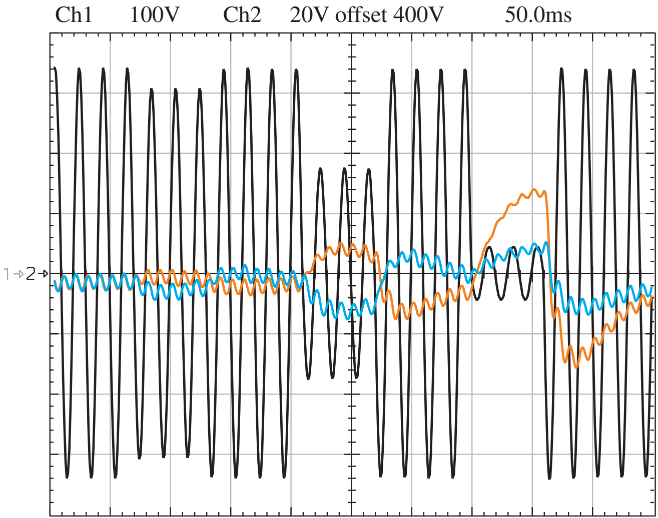
Bus Voltage Controller

- The bus voltage controller starts to adapt g in order to restore the power balance
- After three net periods, the currents of the converters with different control strategies are equal again.
- Due to current limitation, the bus voltage controller cannot always balance the incoming and outgoing power.
  - Especially during deep voltage dips.
  - Bus voltage keeps rising until the dip disappears, or until the converter shuts down.

Experimental Results: 1000 W



Experimental Results: 500 W

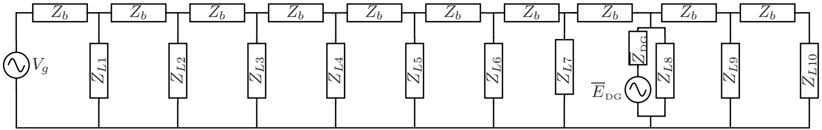


Overview

Model of a Radial Feeder

Active and reactive power of the loads in nominal conditions

	POC1	POC2	POC3	POC4	POC5	POC6	POC7	POC8	POC9	POC10
P [kW]	5	7	3	4.5	9	10	3	1	2	5
Q [kVAR]	1	0.5	0.2	3	0	0	1	0	4	2



Schematic overview of the distribution feeder

Thévenin Equivalent Model

The converter reacts according to:

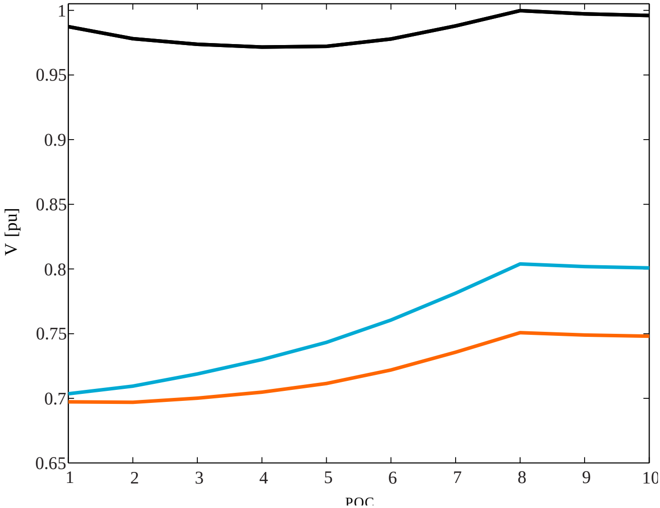
$$i_{\mathrm{L}}^{*} = g\sin(\theta_{\mathrm{PLL}}) + g_{\mathrm{h}}\left(v_{\mathrm{g}} - \sin(\theta_{\mathrm{PLL}})\right) \tag{1}$$

The corresponding Thévenin equivalent is given by:

$$\begin{aligned} \overline{Z}_{\mathrm{DG}} &= \frac{1}{g_{\mathrm{h}}} \\ \overline{E}_{\mathrm{DG}} &= \frac{g_{\mathrm{h}} - g}{g_{\mathrm{h}}} V_{\mathrm{g}}^{\mathrm{nom}} e^{j\delta} \end{aligned} \tag{2}$$

Setting g_{h} to zero yields a model for the sinusoidal convertor.

Voltage Profiles



Overview

Thanks to the implementation of the damping control strategy:

- Reduced bus voltage variations
- Converter-connected DG units have a better voltage dip immunity.
- Converter-connected sensitive equipment can be protected as well.
- Additional power is injected in the grid during dips.
- Retained voltage is kept higher.

Power Quality improvement as secondary function can be implemented without violating the primary function of the device.