Active damping of oscillations in LC-filter for line connected, current controlled, PWM voltage source converters

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The challenge

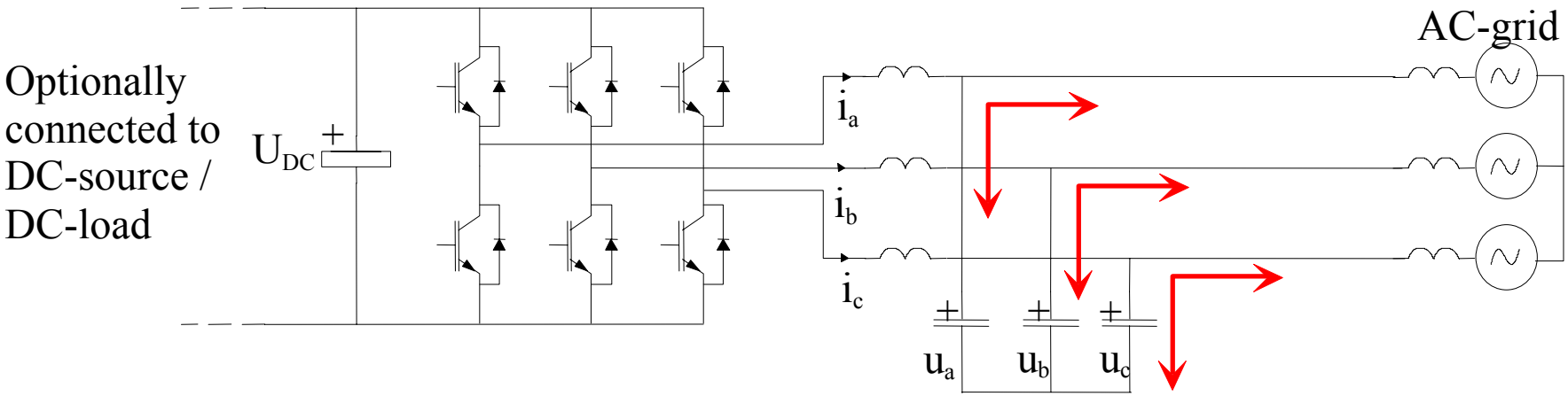
- A low pass LC-filter is a commonly used method to reduce the switching ripple currents and voltages at the terminals of line connected PWM converters
- The LC-filter introduces risk of oscillations in converter terminal voltage due to resonance between LC-filter capacitor and AC-grid reactance
- Oscillations can be initiated by nearby load changes or by periodic disturbances in the grid (e.g. thyristor rectifiers).
- The challenge is to modify the control system in such a way that oscillations are damped without affecting the basic control tasks of the converter

Applicability

- Filter oscillations is most likely to be a problem when the natural frequency of the oscillation is low (poorly damped)
- The worst cases will typical be those were the converter rating becomes comparable to the upstream transformer (or generator) rating.
- A typical example is emergency operation of isolated grids were converter ratings may become comparable to the emergency generator ratings.
- Other examples are ship and offshore power systems and distributed production units connected to a weak grid.

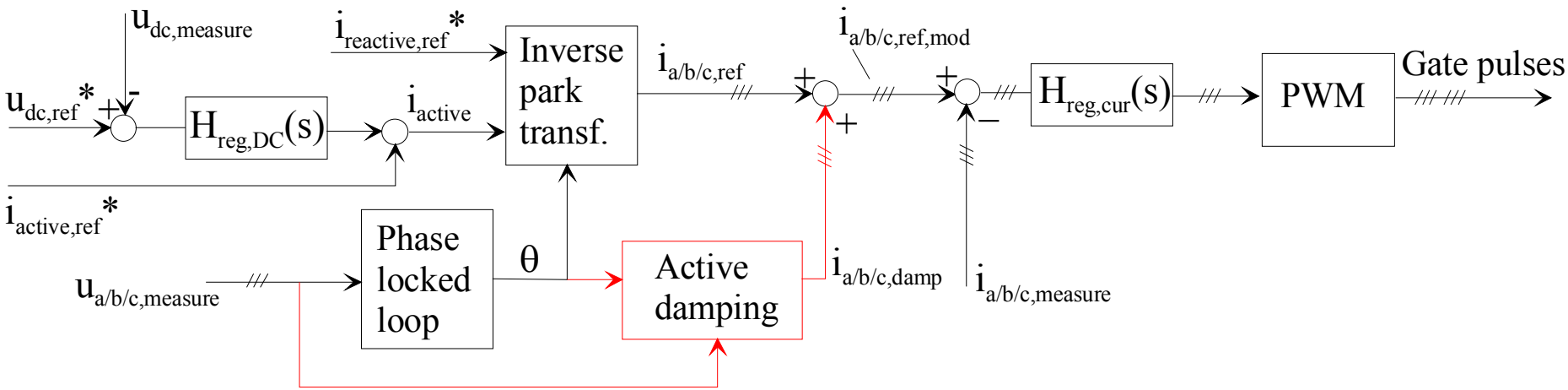
The power circuit

- Current controlled, line connected, PWM voltage source converter (For instance operated as active rectifier / inverter, STATCOM or active filter)
- The focused oscillation are illustrated by red arrows in the figure



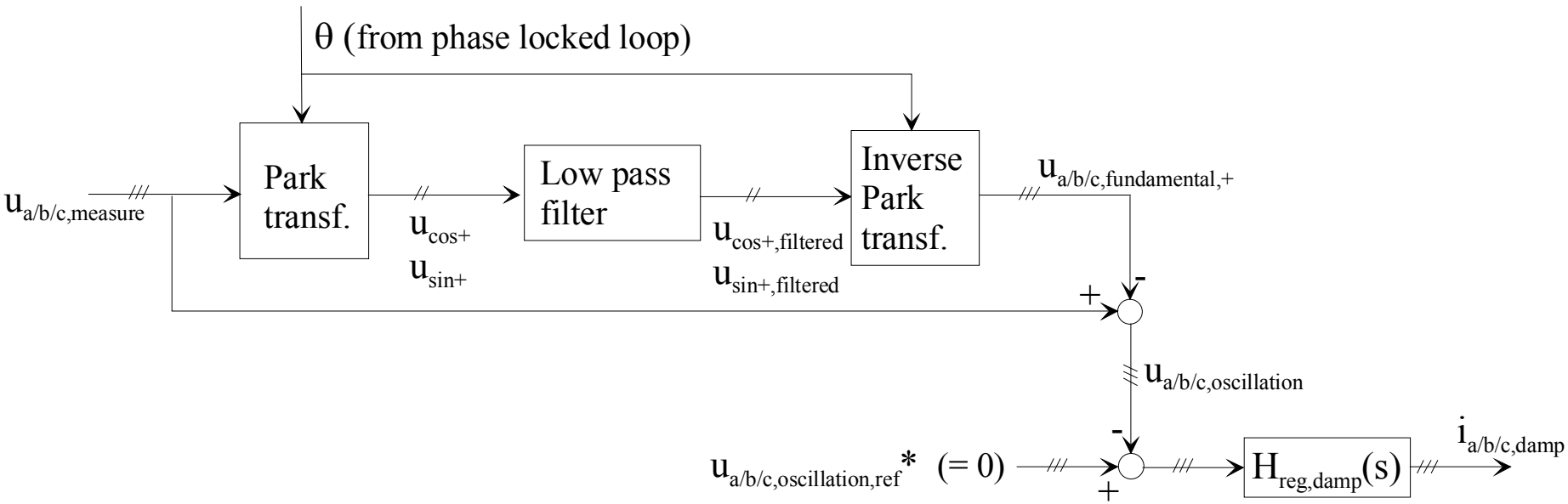
Control system

- Closed loop control of filter inductor current and DC-link voltage, PWM
- Measures DC-link voltage, minimum two filter inductor currents and two line voltages.
- Synchronisation by phase locked loop
- Active damping is an ”add-on feature” (red in the figure)



The active damping method

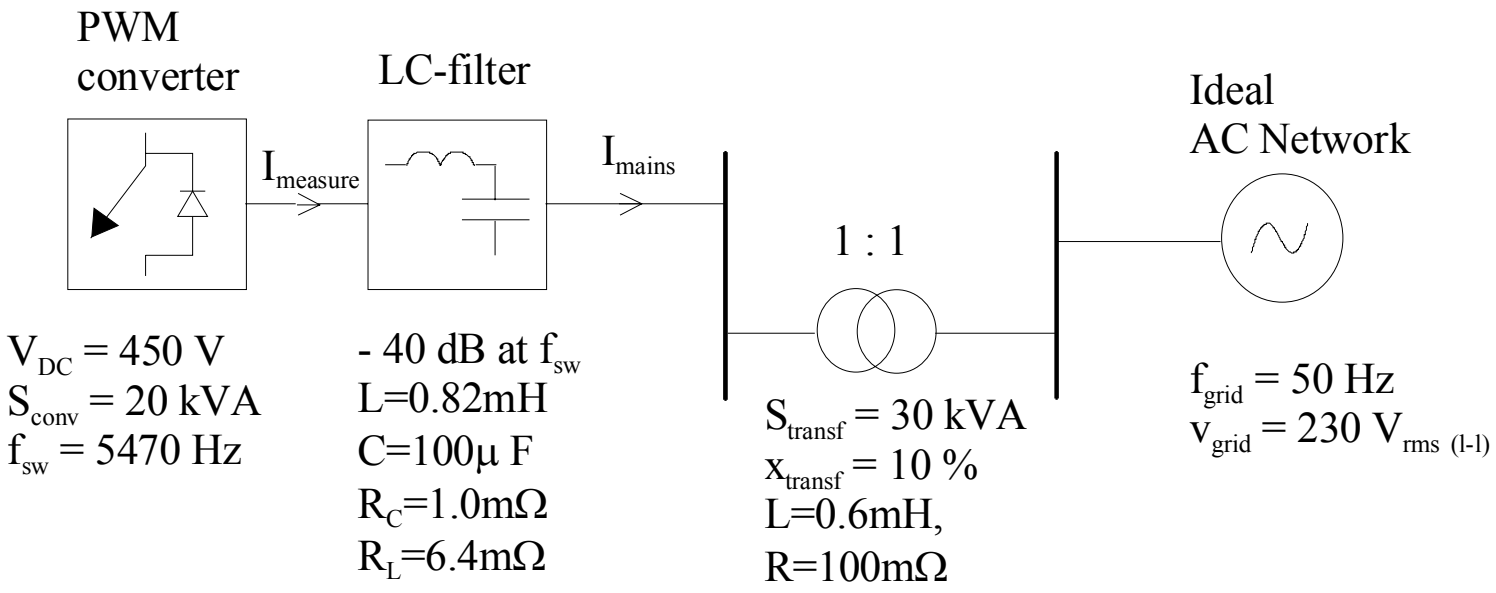
- The oscillating component of the capacitor voltage is extracted (the non-fundamental component)
- The error in the capacitor voltage is found by subtracting the oscillating component from its reference (=0)
- The error is amplified and added to the reference signal for the current controller.



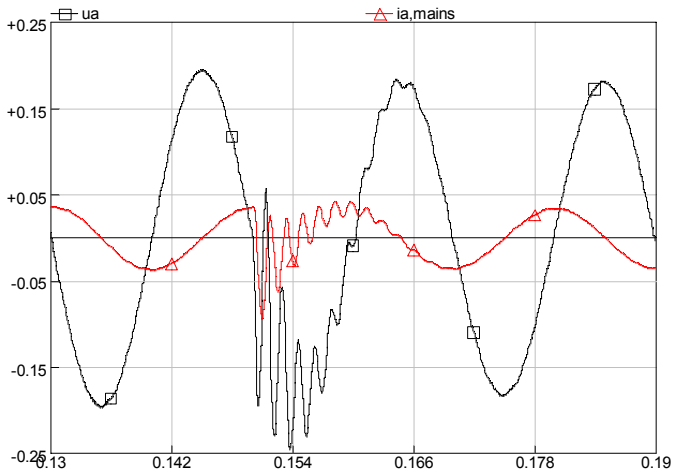
Demonstration by simulation

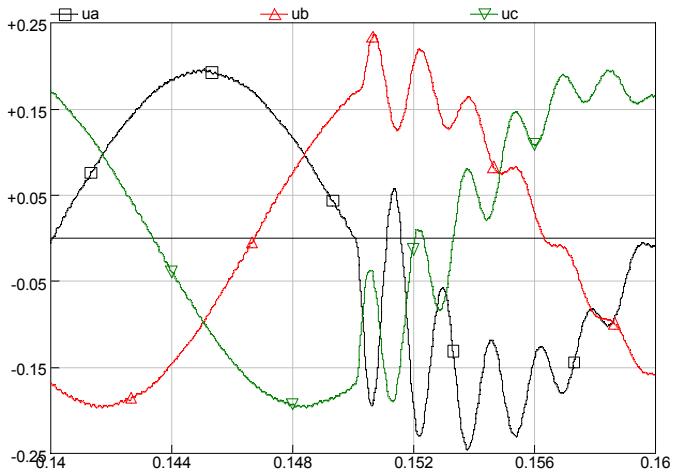
- Application: PWM converter connected to the AC-grid at a point with low short circuit capacity compared to converter kVA rating

- Demonstration of damping of oscillations after a step reversal of the reference for reactive current



Active damping disabled





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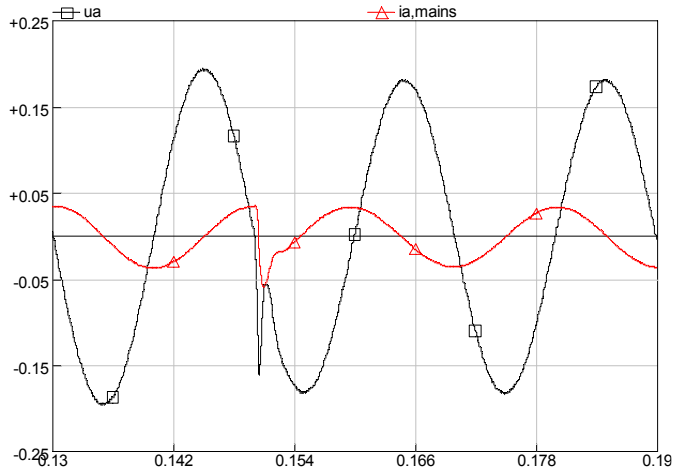
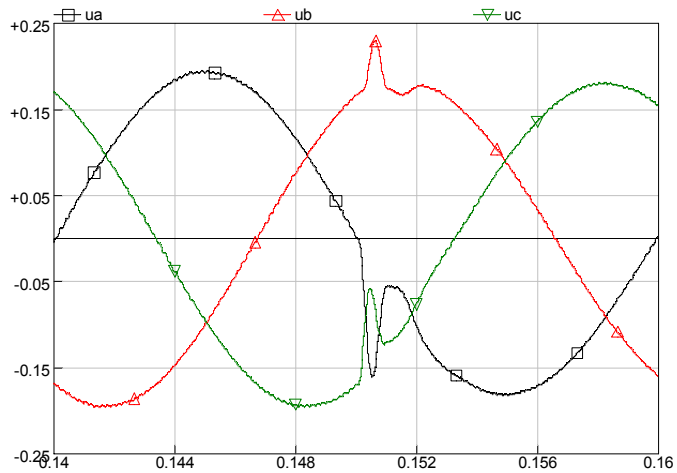




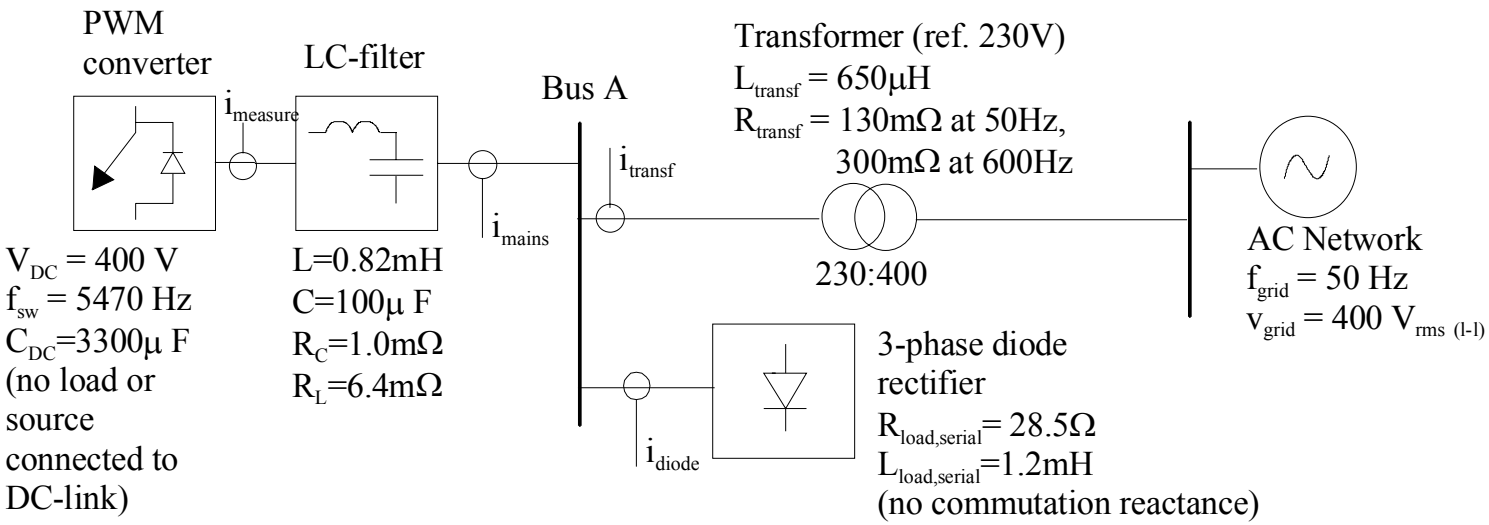
Phase a filter capacitor voltage (black)

Phase a current into AC-grid (red)

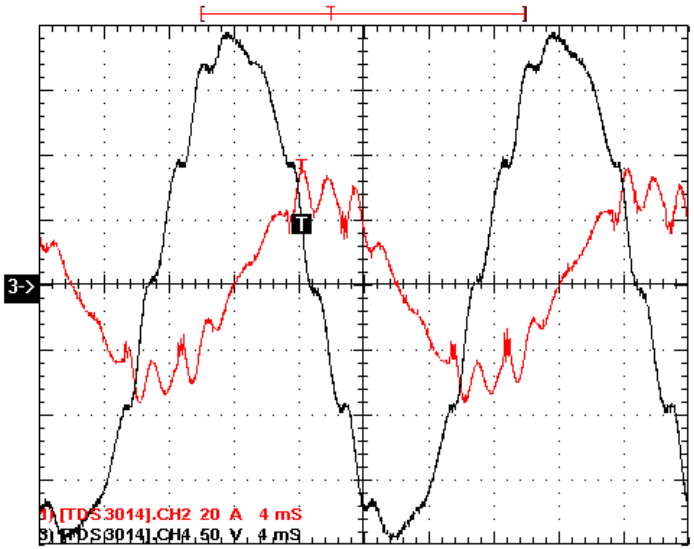
Filter capacitor voltages (phase a, b, c)

Laboratory demonstration

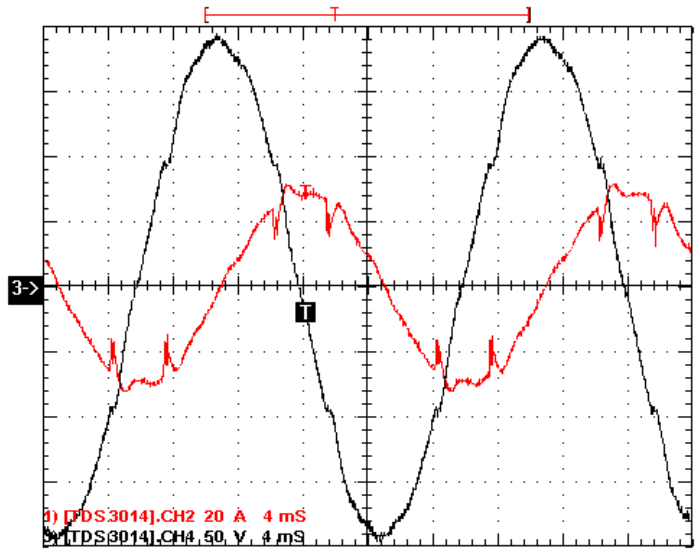
- Converter connected to a weak bus
- Three-phase diode rectifier connected to the same bus
- Measurements demonstrates that the active damping suppresses LC-filter filter oscillations trigged by the harmonics of the diode rectifier



✗ Active damping disabled



√ Active damping enabled



Phase voltage at bus A (black)

Transformer current (red)

Conclusions

- Introduction of active damping is a possible measure for reduction of oscillations due to low pass LC-filters of line connected current controlled PWM converters
- Simulations and measurements show that the method works as intended
- The voltage quality at the point of connection can be maintained in cases were filter oscillations is to be expected when the low pass LC-filter is introduced