

Active Damper for Power Electronics Based Systems

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Outline



- Background**
- Concept: Damping Resistance**
- Realization of the Active damper**
- Experimental Results**



Background



Background

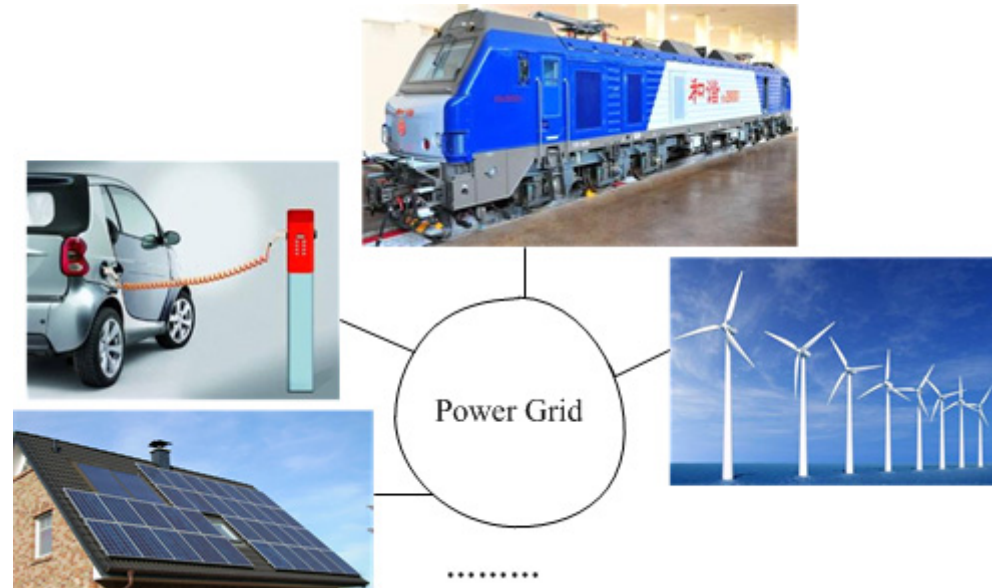
Concept: Damping Resistance

Realization of the Active damper

Experimental Results



□ Power-Electronics Converters



- Grid impedance
- LCL filters of the grid-connected converters
- Limited control bandwidth in high power applications



Harmonic resonance and instability !!!

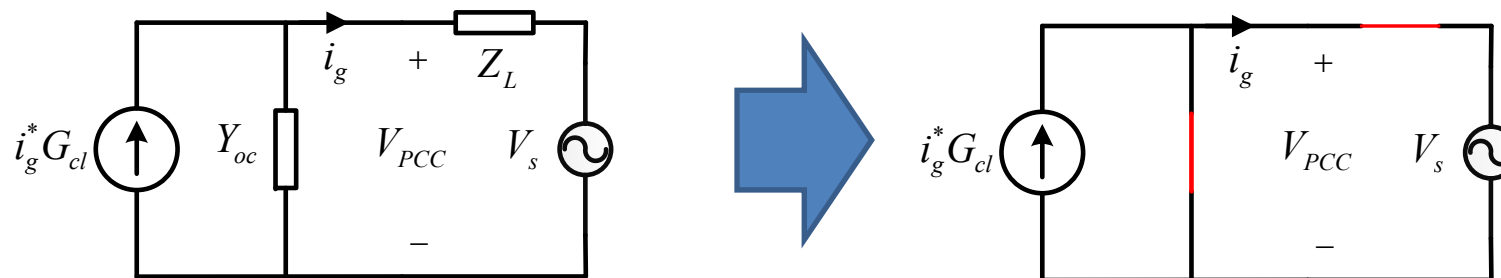
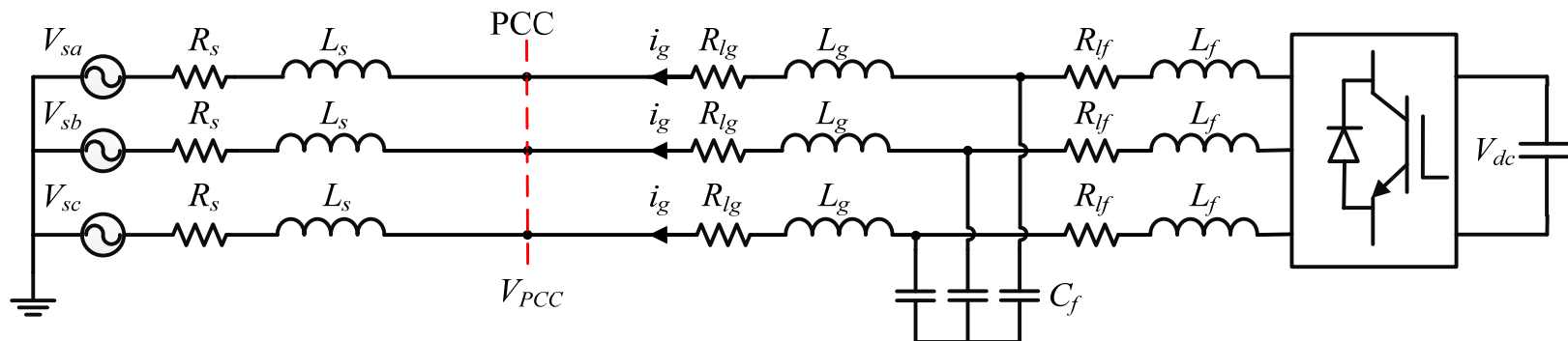


Background



□ Explanation

– Impedance-based Model of Grid Connected Converter



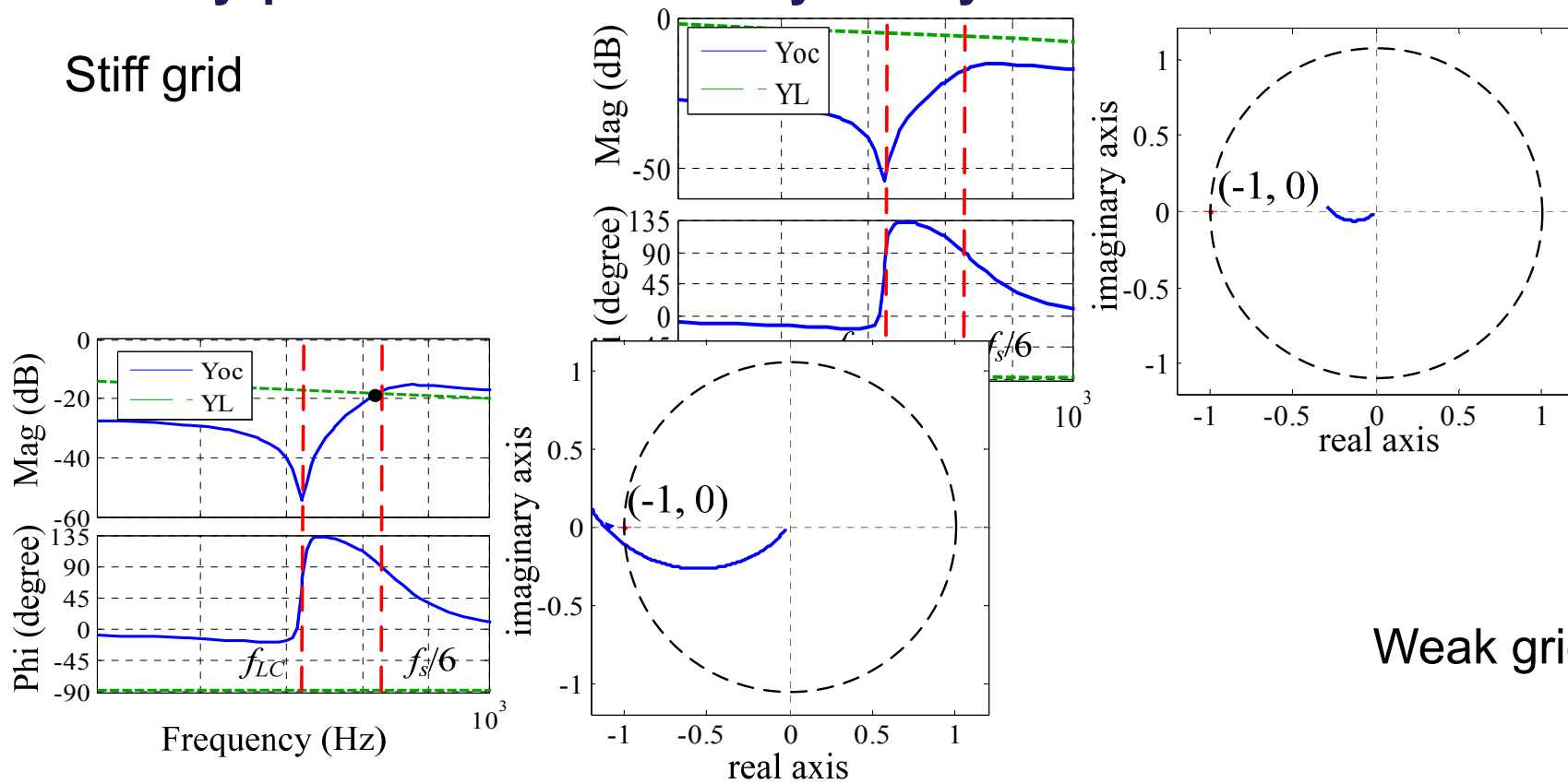
Background



□ Explanation

- Nyquist based stability analysis

Stiff grid





□ Existing Solutions

– Passive damping

- High power loss;
- Sensitive to parameter changing.

– Active damping

- Within the control loop of converter;
- Limited by the control bandwidth.



Other possibilities?

Active damper



Concept: Damping Resistance



Background

Concept: Damping Resistance

Realization of the Active damper

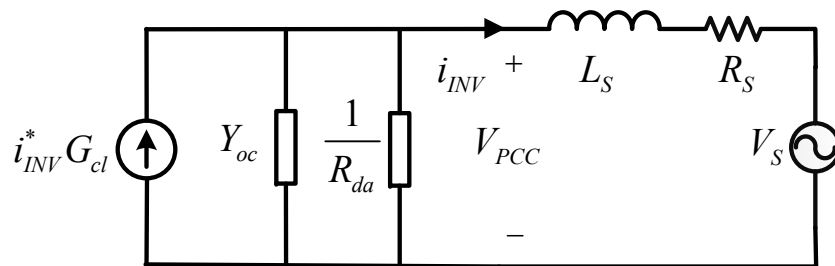
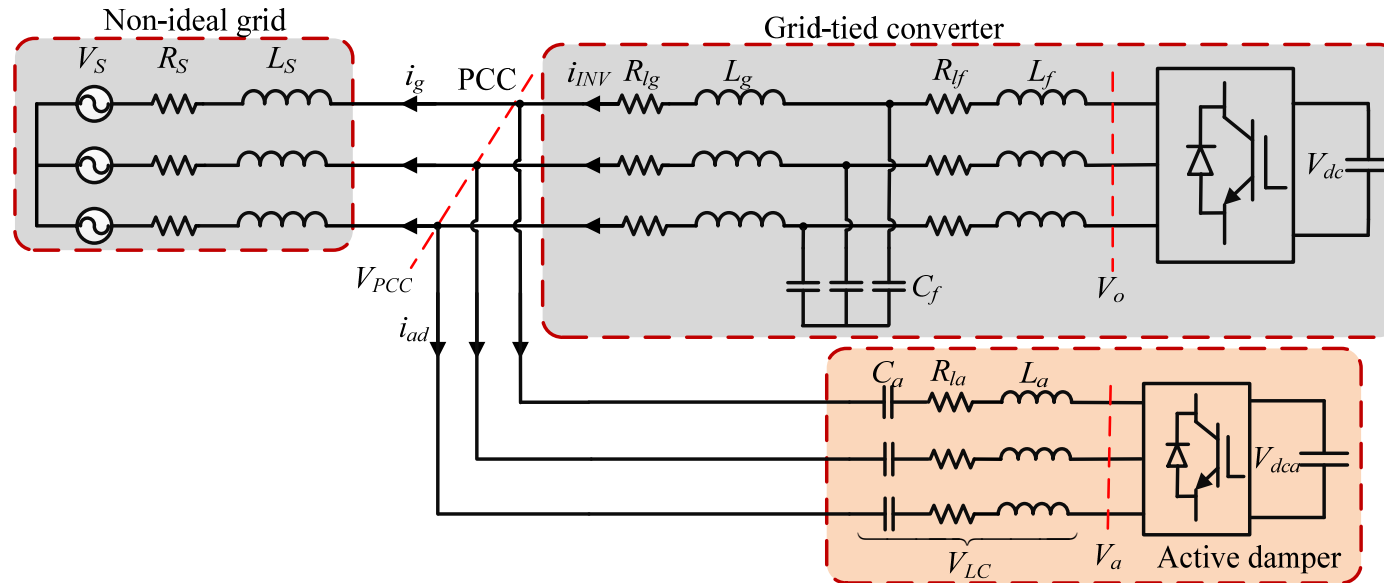
Experimental Results



Concept: Damping Resistance



□ System with Active Damper



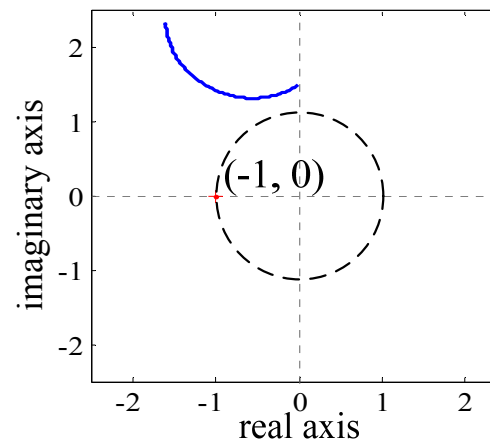
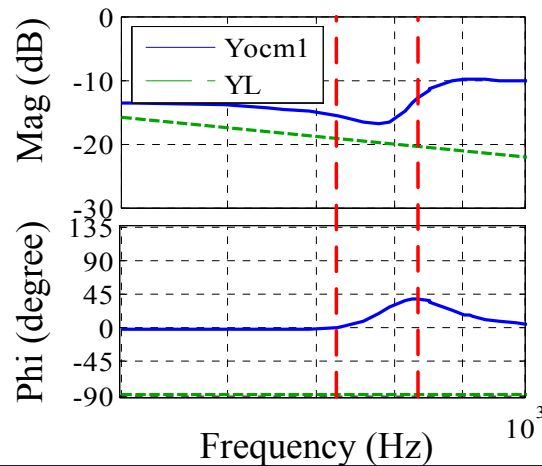
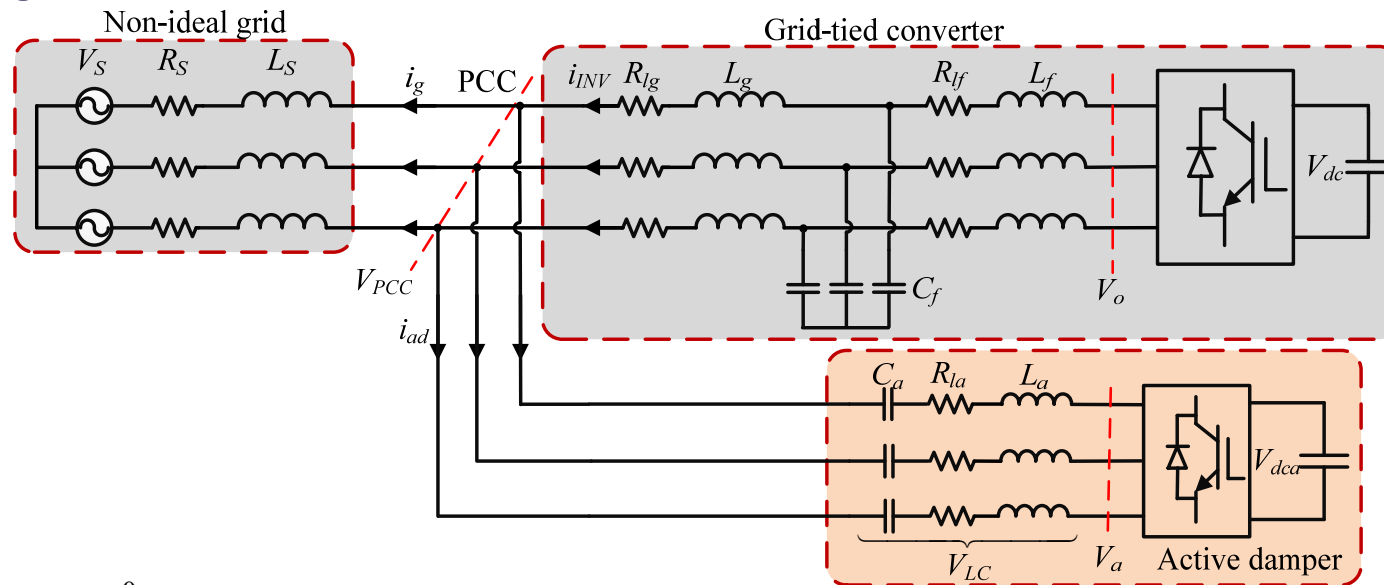
$$\left| Y_{oc}(\omega) \right|_{\omega = \frac{\pi f_s}{3}} = \frac{1}{R_{da, \max}}$$



Concept: Damping Resistance



System with Active Damper



Realization of the Active damper



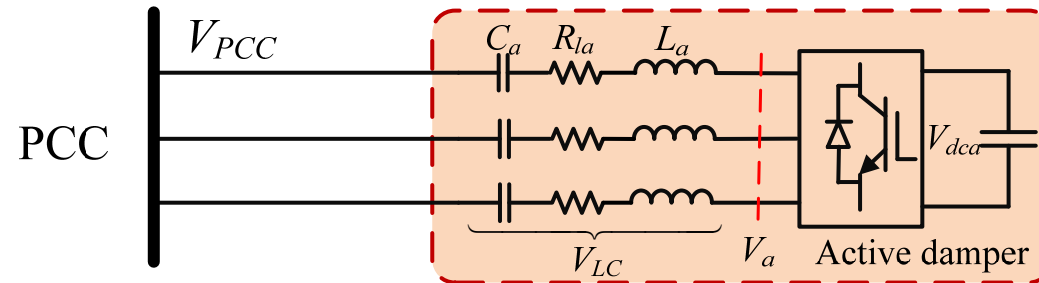
- Background
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Realization of the Active damper



□ Topology



Fundamental voltage of the grid can be sustained by the series LC filter, which brings the following benefits:

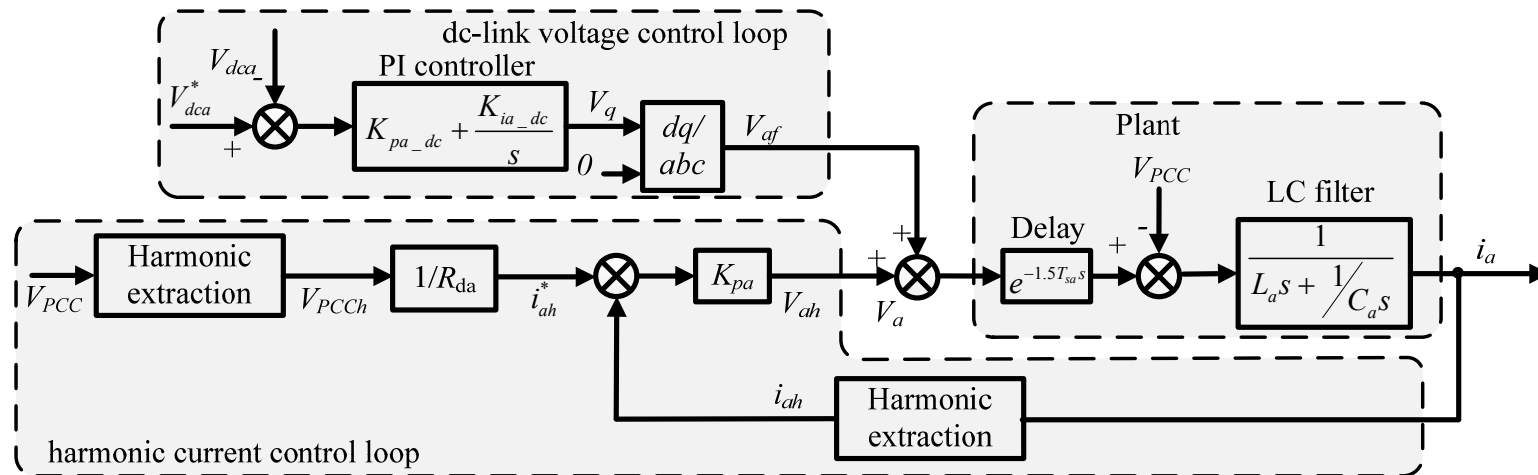
- Low power rating;
- Low dc-link voltage;
- High switching frequency.



Realization of the Active damper



□ Control strategy



Composed of two parts:

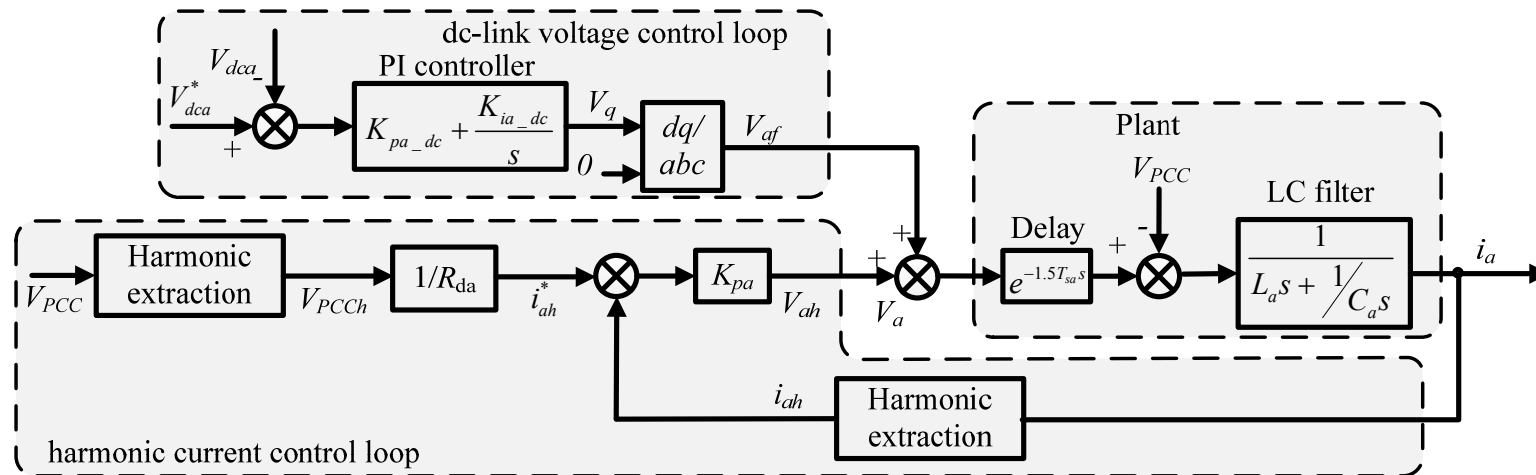
- Dc-link voltage control loop
- Harmonic current control loop



Realization of the Active damper



Control strategy



DC-link voltage control loop:

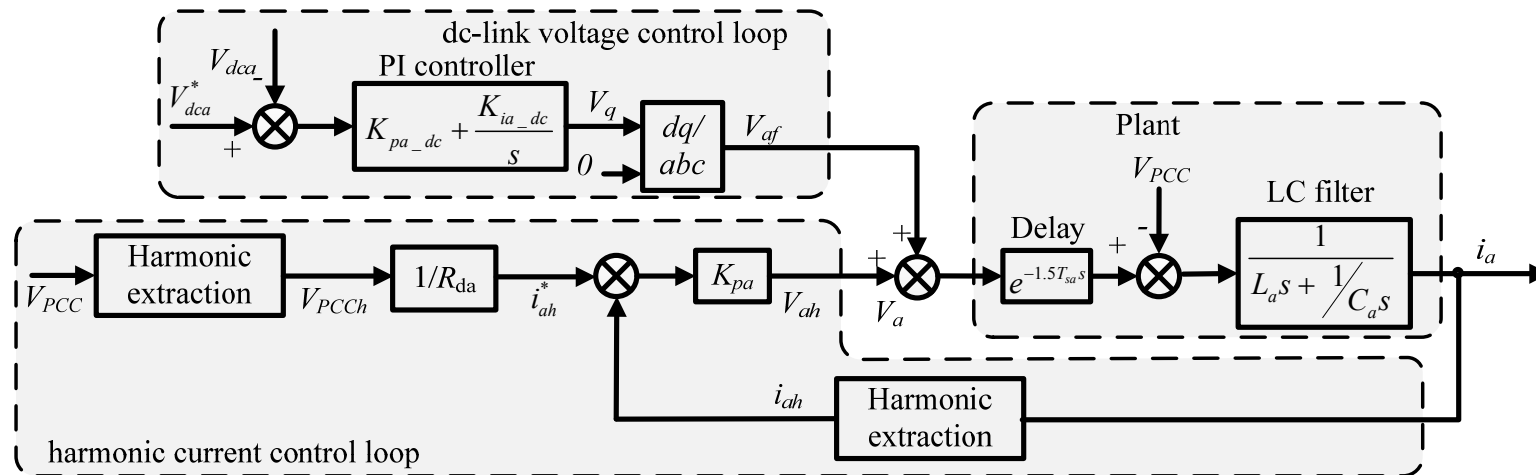
- Carried out at q-axis at the fundamental frequency.
- The output of the PI controller are directly fed to the PWM modulation block.



Realization of the Active damper



□ Control strategy



Harmonic current control loop:

- Responsible for mimic the damping resistance;
- Decoupled with the dc-link voltage control loop through a harmonic extraction block.

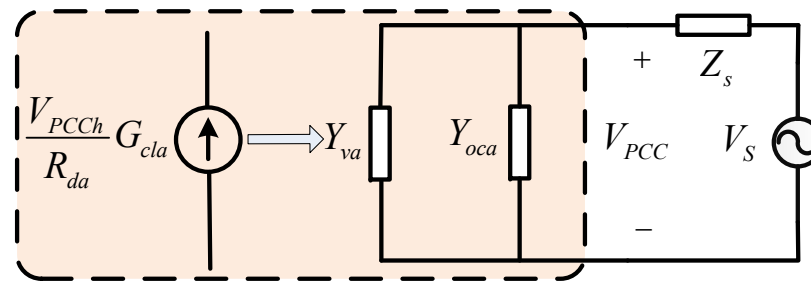


Realization of the Active damper



□ Impedance model of the active damper

Structurally, the active damper is no different from a grid-tied converter, except with a lower rating and the series LC filter as the controlled plant.



The usual current source in the Norton circuit is replaced by an admittance Y_{va}

$$Y_{va} = \frac{1}{R_{da}} G_{cla}$$



Realization of the Active damper

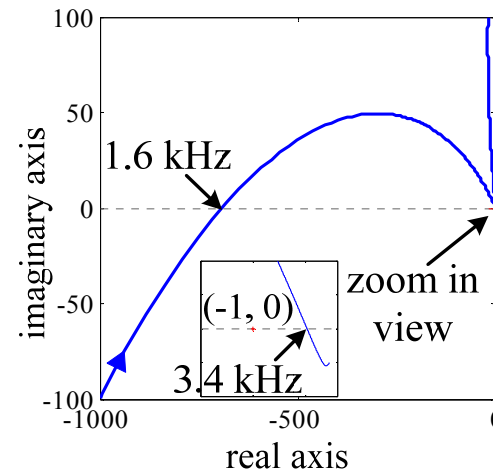
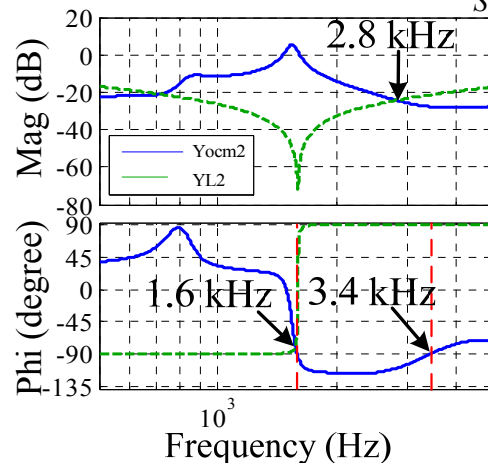


□ A special problem for the active damper

Y_{va} will be non-passive above the bandwidth of the active damper, introducing new possibility for harmonic resonance at higher frequencies with grid capacitance (above the control bandwidth of the active damper).

$$Y_{ocm2} = \underbrace{Y_{va} + Y_{oca}}_{\text{active damper}} + \underbrace{Y_{oc}}_{\text{grid converter}} = Y_{da} + Y_{oc}$$

$$Y_{L2} = \frac{1}{L_S s + R_S} + s C_p$$



Realization of the Active damper



□ A special problem for the active damper

Solution:

A simple first order low-pass filter.

$$G_{lpf} = \frac{\omega_c}{s + \omega_c}, \omega_c = 2\pi f_c$$

Design of the low-pass filter

- The purpose is to avoid deteriorating damping effect intended for the grid converter over its non-passive range.
- Reducing the non-perfection of the current control loop of the active damper.

Slightly higher than the upper limit of the non-passive region of the grid converter.

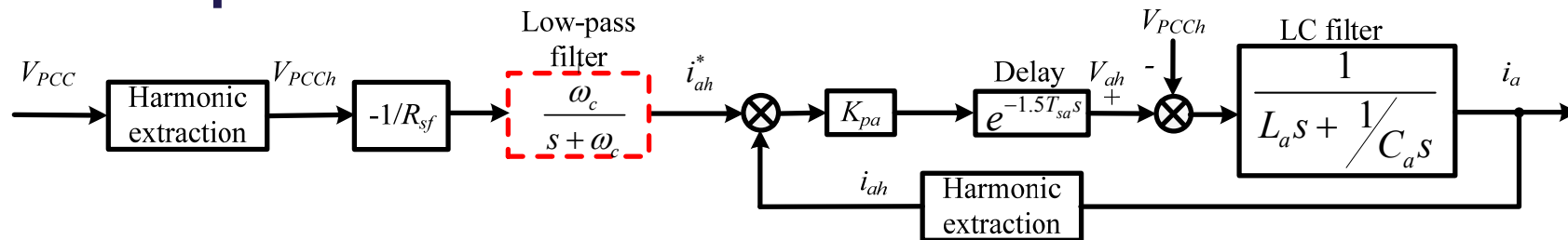
$$f_c = 1 \text{ kHz}$$



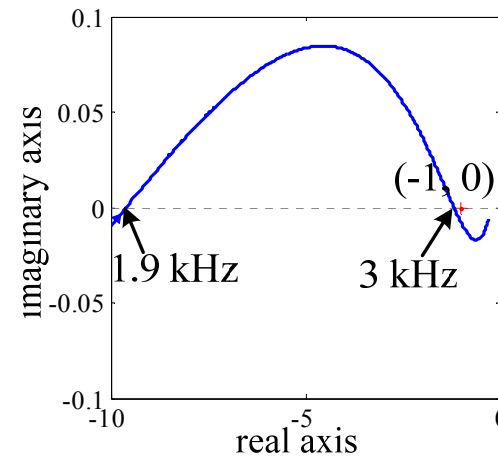
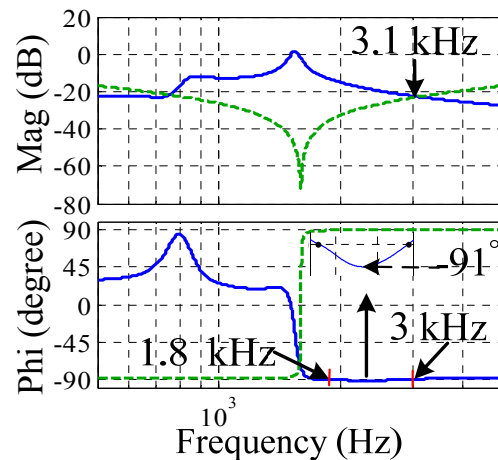
Realization of the Active damper



□ Modified harmonic current control loop



$$Y_{ocm3} = \underbrace{\frac{1}{R_{da}} G_{lpf} G_{cla}}_{\text{active damper}} + Y_{oca} + \underbrace{Y_{oc}}_{\text{grid converter}}$$



Experimental Results



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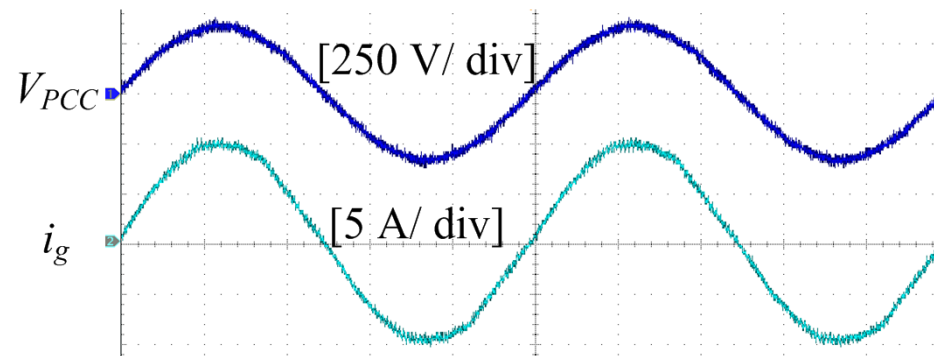


Experimental Results

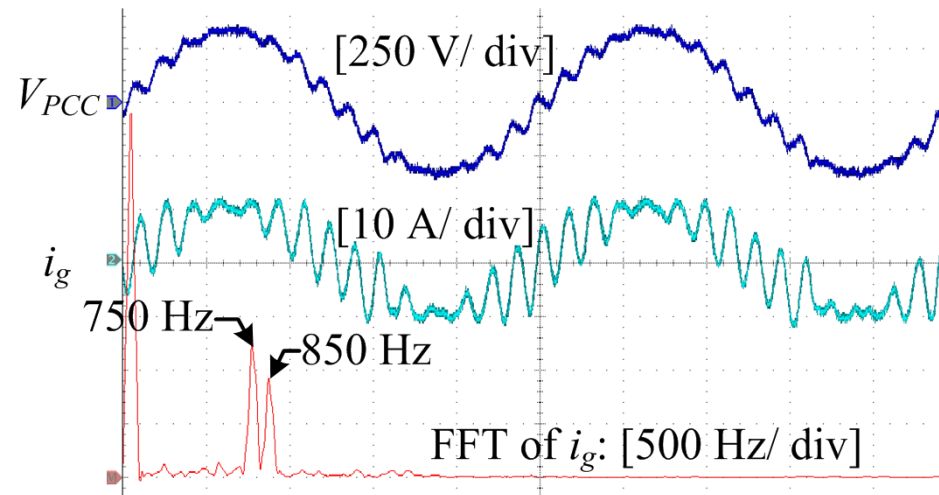


□ Stability analysis of the grid converter

Stiff grid



Weak grid

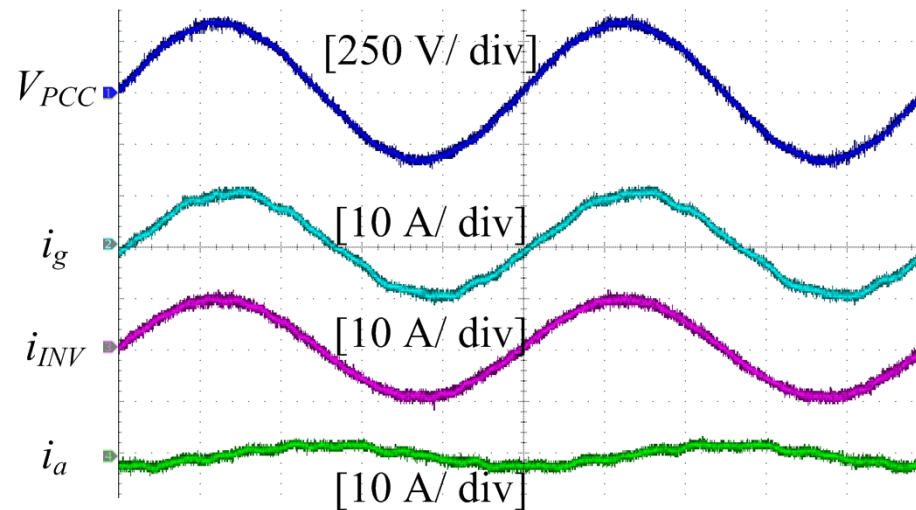


Experimental Results

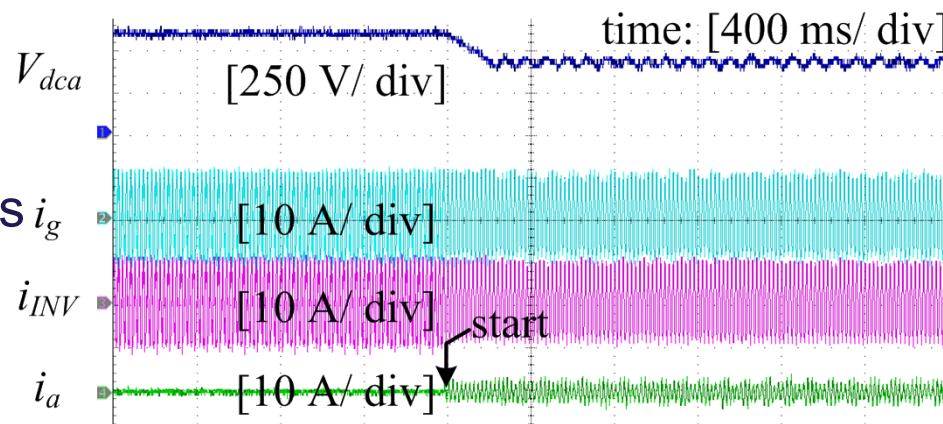


□ Performance of the active damper

Steady state



Startup process

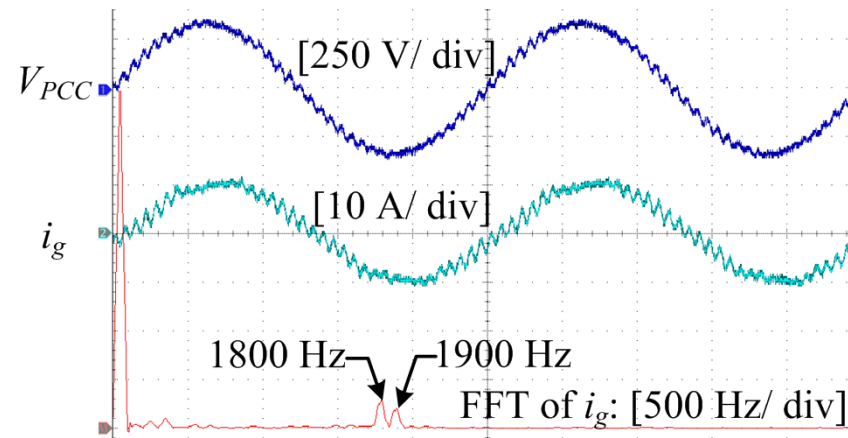
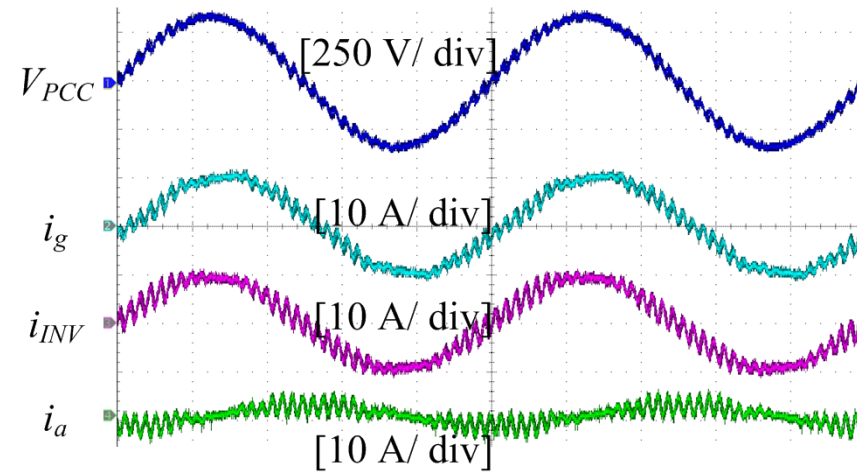


Experimental Results



□ Effect of the low-pass filter

Without
low-pass
filter

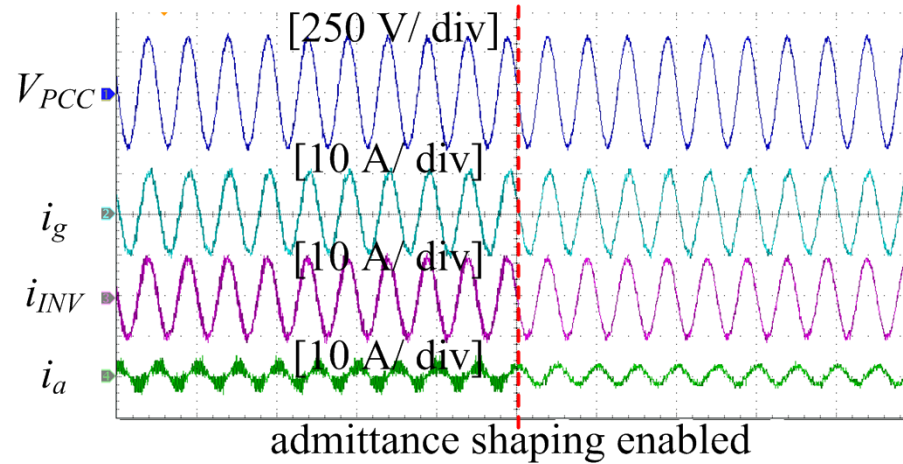
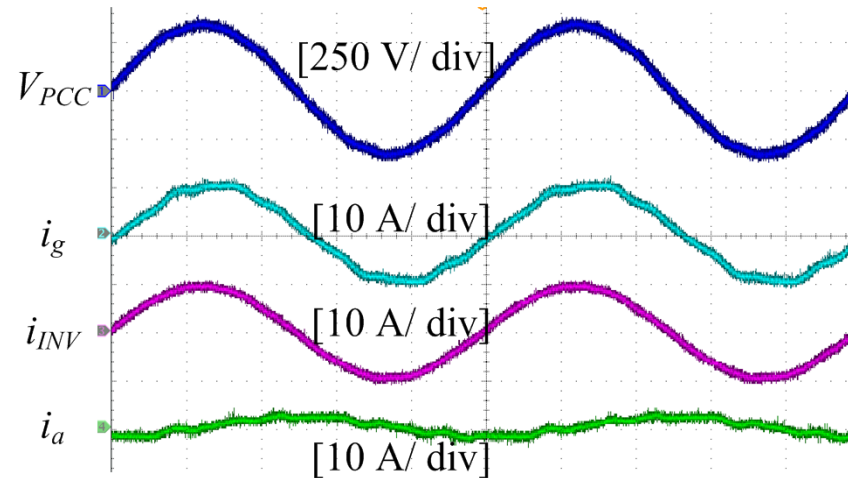


Experimental Results



□ Effect of the low-pass filter

With low-pass filter



Thank You! Questions?

**“ THE HIDDEN HARMONY IS
BETTER THAN THE OBVIOUS ”**

- P. PICASSO



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