Observer state feedback current control of grid-connected voltage source inverters with LCL filter

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Outline

1. MSE Group “Control of Renewable Energy Systems (CRES)”

2. Observer state feedback (SF) current control of grid-connected voltage source inverters (GC-VSIs) with LCL filter [1]

Outline

Group “Control of renewable energy systems (CRES)”

Research projects (7 PhD candidates, 1 Post-Doc & 3 PhD collaborations)

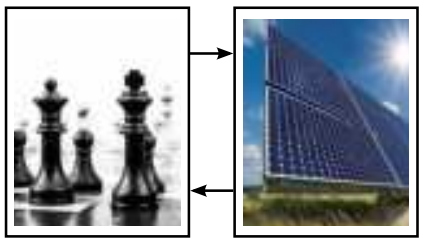
Large-scale WTS

Efficiency+Reliability

Small-scale WTS

Reluctance SM

Model predictive control for RES



Real-time applicability

Airborne Wind Energy

Fault-tolerant control

Geothermal energy

Fault-tolerant control

Wave energy (SinnPower)

Efficiency+Reliability

Electric vehicles (BMW)

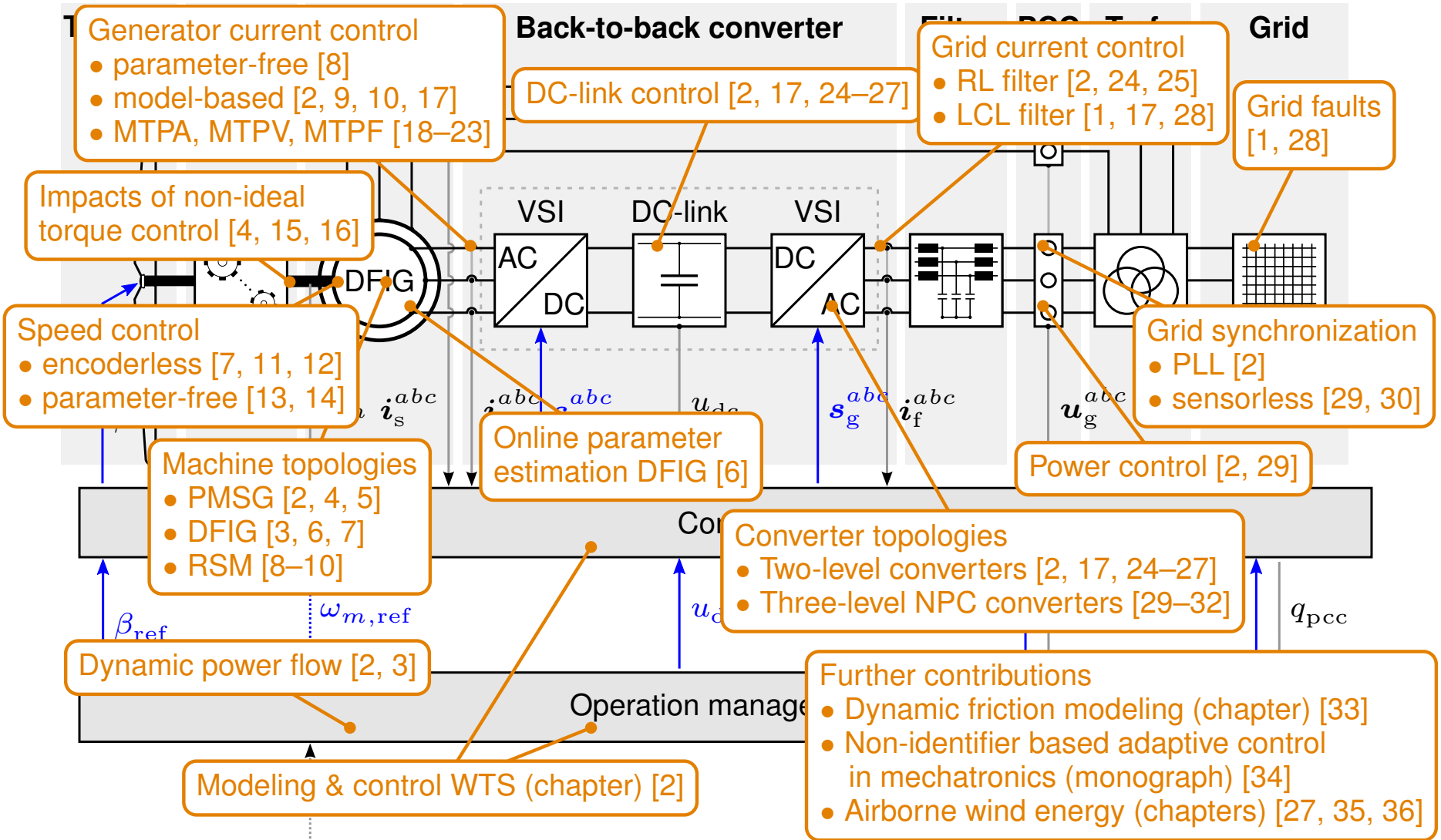
Efficiency+Reliability

Power systems

Four-wire system

Group “Control of renewable energy systems (CRES)”

Research focus and publications: **Electrical** components of e.g. large-scale wind turbine systems



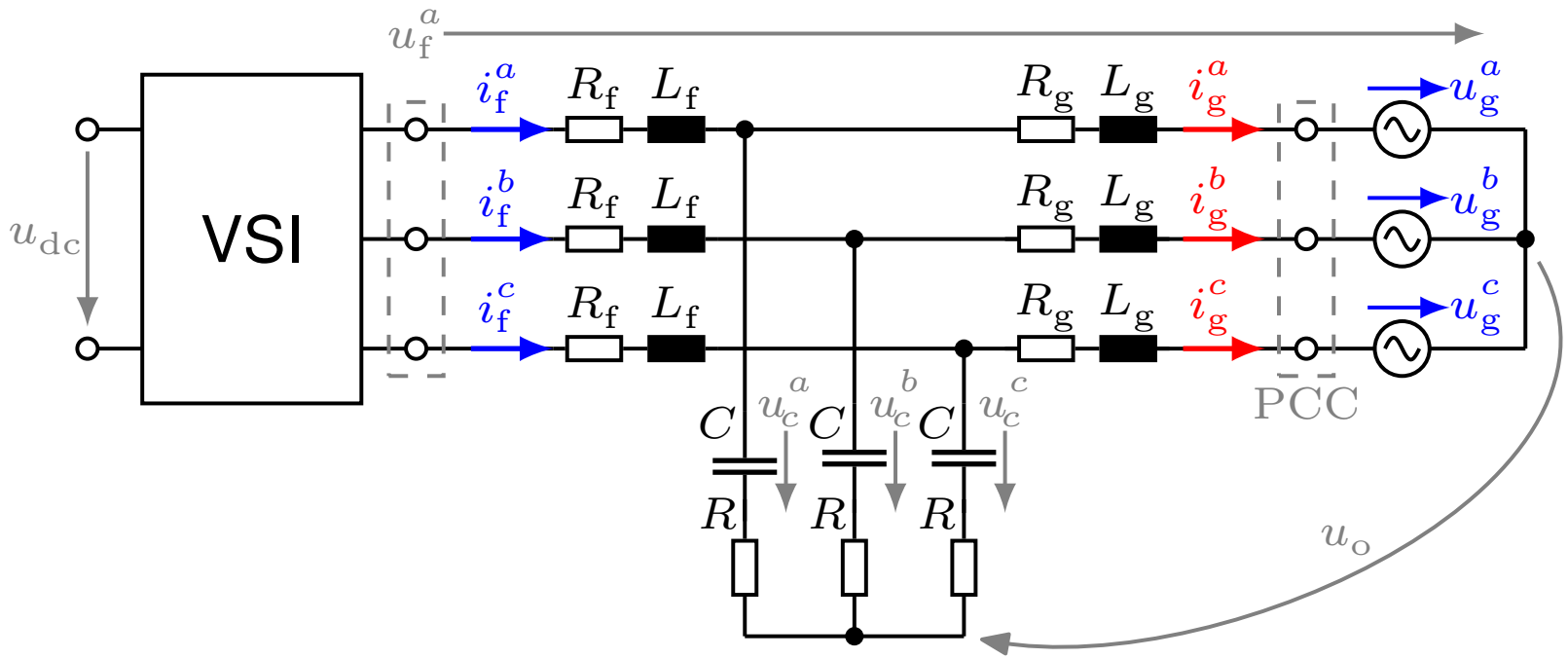
Outline

2 Observer state feedback (SF) current control of grid-connected voltage source inverters (GC-VSIs) with LCL filter [1]

- Electrical network and problem statement
- Block diagram of overall control structure
- Implementation
- Simulation results

Observer SF control for GC-VSIs with LCL filter

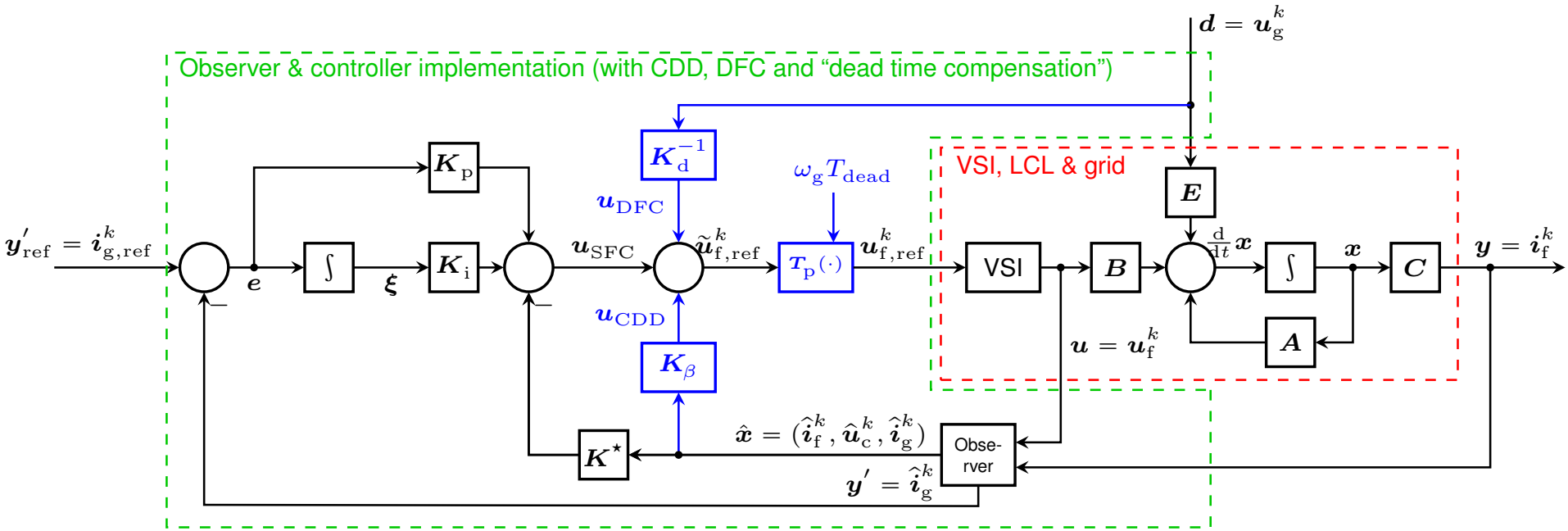
Electrical network and problem statement



- Control of grid currents $\boldsymbol{i}_{\mathrm{g}}^{abc}$ (Active and reactive power)
- Measurement of inverter-side currents $\boldsymbol{i}_{\mathrm{f}}^{abc}$ and grid voltage $\boldsymbol{u}_{\mathrm{g}}^{abc}$
- active damping of resonance frequency $\omega_{\mathrm{res}} = \sqrt{\frac{L_{\mathrm{f}}+L_{\mathrm{g}}}{CL_{\mathrm{f}}L_{\mathrm{g}}}}$ of LCL filter

Observer SF control for GC-VSIs with LCL filter

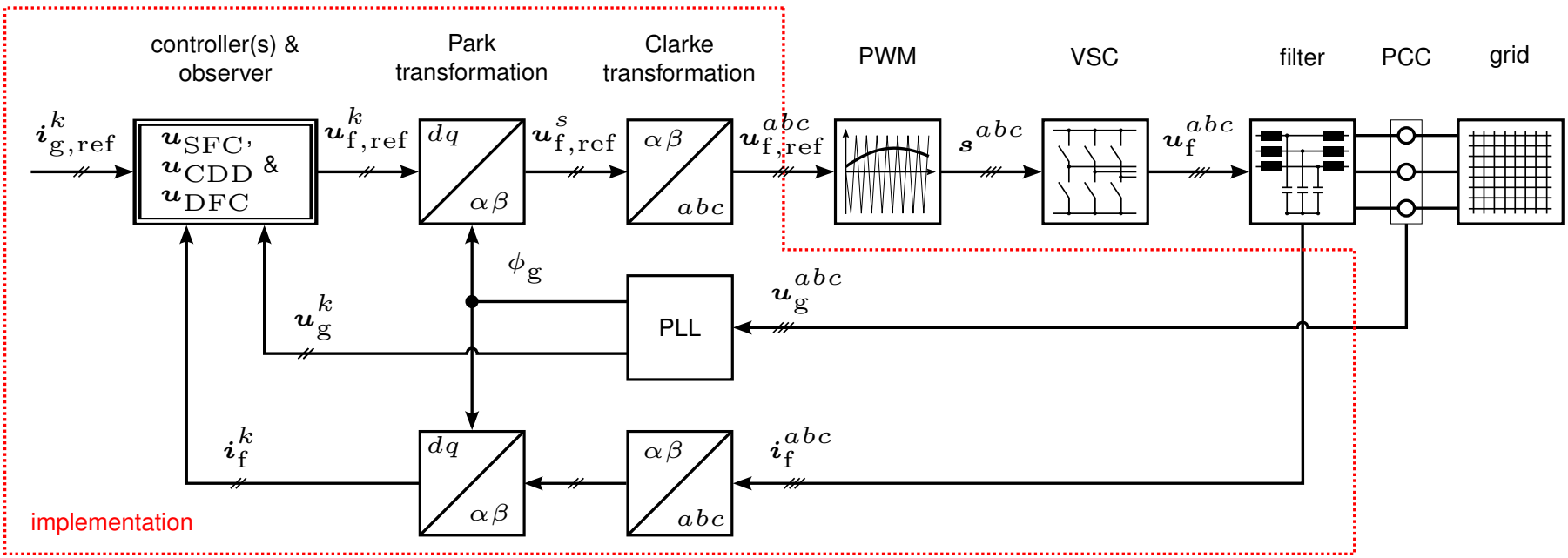
Block diagram of overall control structure



- State feedback controller (SFC): $\boldsymbol{u}_\mathrm{SFC}(t) = \boldsymbol{K}^\star \hat{\boldsymbol{x}}(t) + \boldsymbol{K}_\mathrm{p} \boldsymbol{e}(t) + \boldsymbol{K}_\mathrm{i} \int_0^t \boldsymbol{e}(\tau)\,\mathrm{d}\tau$
- Luenberger Observer for state estimation $\hat{\boldsymbol{x}}(t)$ (only using $\boldsymbol{i}_\mathrm{f}^k$, $\boldsymbol{u}_\mathrm{f}^k$ & $\boldsymbol{u}_\mathrm{g}^k$)
- Current dynamics decoupling (CDD): $\boldsymbol{u}_\mathrm{CDD}(t) = \boldsymbol{K}_\beta \hat{\boldsymbol{x}}(t)$
- [Disturbance feedforward comp. (DFC): $\boldsymbol{u}_\mathrm{DFC}(t) = \boldsymbol{K}_\mathrm{d}^{-1} \boldsymbol{u}_\mathrm{g}^k(t)$ ($\boldsymbol{u}_\mathrm{g}^k$ from PLL)]
- [Dead time compensation: $\boldsymbol{u}_\mathrm{f,ref}^k(t) = \boldsymbol{T}_\mathrm{p}(\omega_\mathrm{g} T_\mathrm{dead}) \tilde{\boldsymbol{u}}_\mathrm{f,ref}^k(t)$ (ω_g from PLL)]

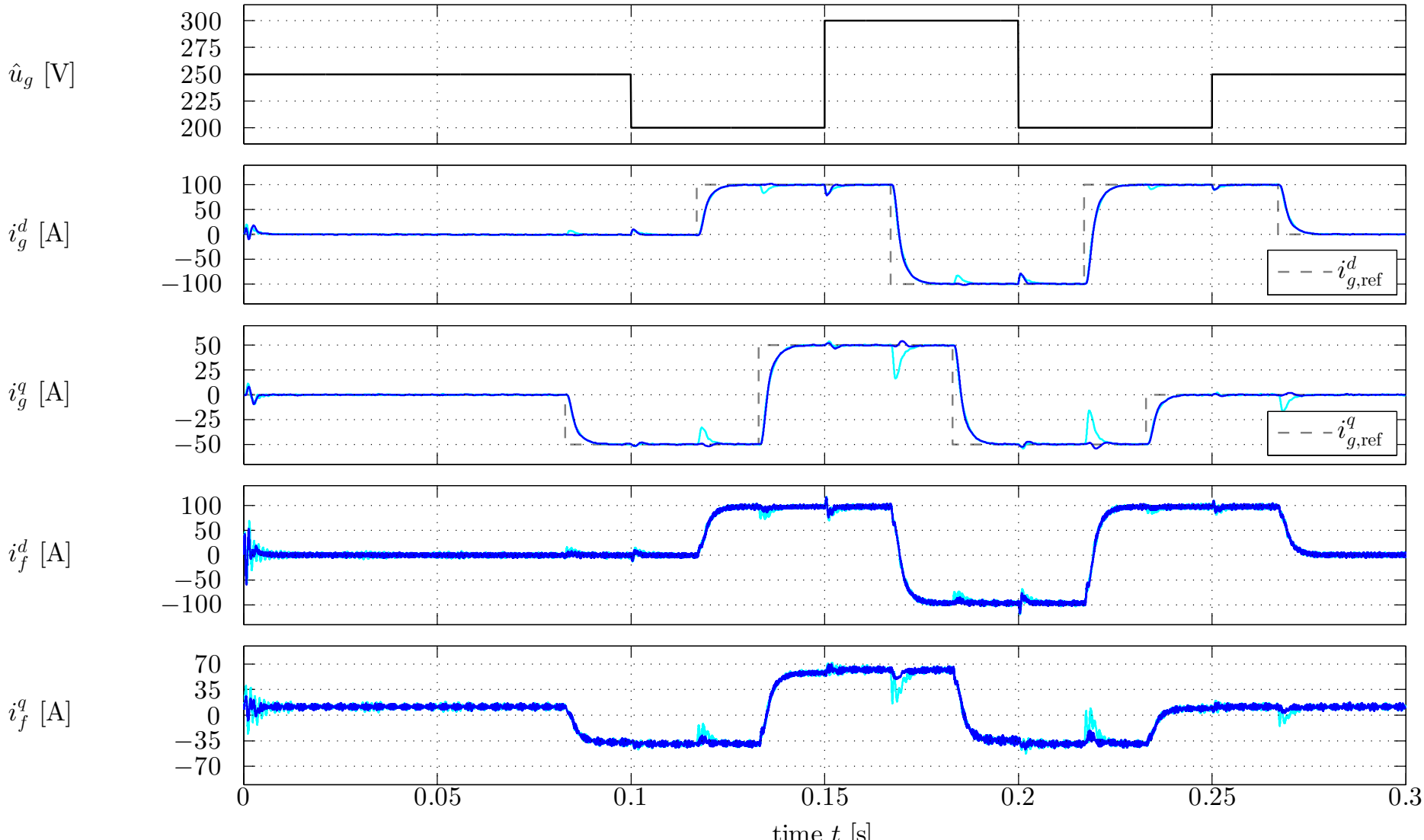
Observer SF control for GC-VSIs with LCL filter

Implementation of controller and observer



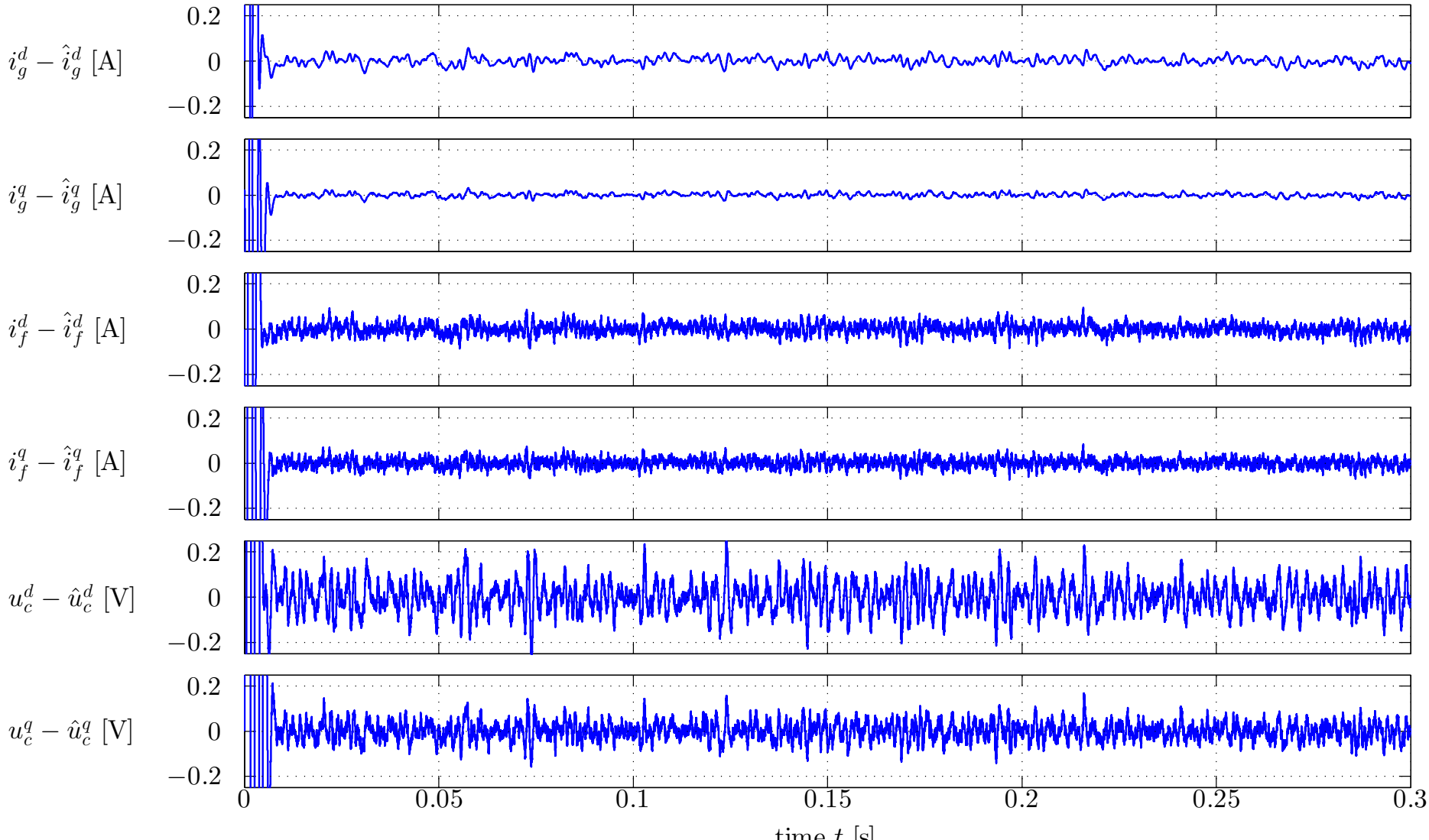
Observer SF control for GC-VSIs with LCL filter

Simulation results: Control performance of SFC with and without CDD



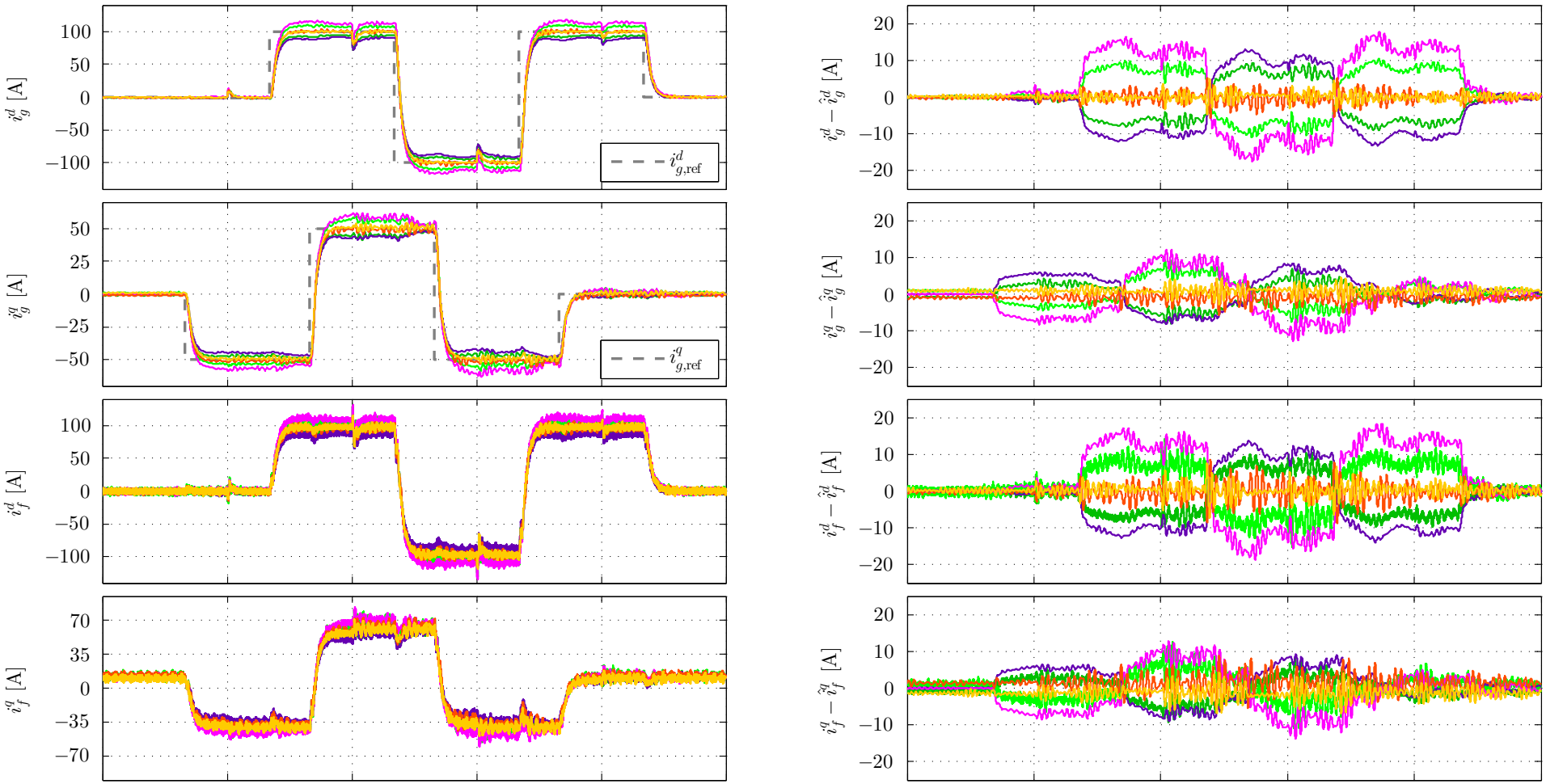
Observer SF control for GC-VSIs with LCL filter

Simulation results: Estimation error of observer for SFC with —— CDD



Observer SF control for GC-VSIs with LCL filter

Simulation results: Robustness of controller & observer (against $\pm 20\%$ parameter variations)



$1.2L_\mathrm{f}$, $0.8L_\mathrm{f}$, $1.2L_\mathrm{g}$, $0.8L_\mathrm{g}$, $1.2C$, and $0.8C$.

Conclusion

Summary and personal assessment

To take home

- State feedback current control of grid-connected VSI with LCL
  - fast closed-loop system with asymptotic tracking (without oscillations),
  - active damping / no resistive damping required $\Longrightarrow$ increased efficiency,
  - robustness (parameter uncertainties) $\Longrightarrow$ applicable in real world,
  - state estimation $\Longrightarrow$ reduction of number of sensors

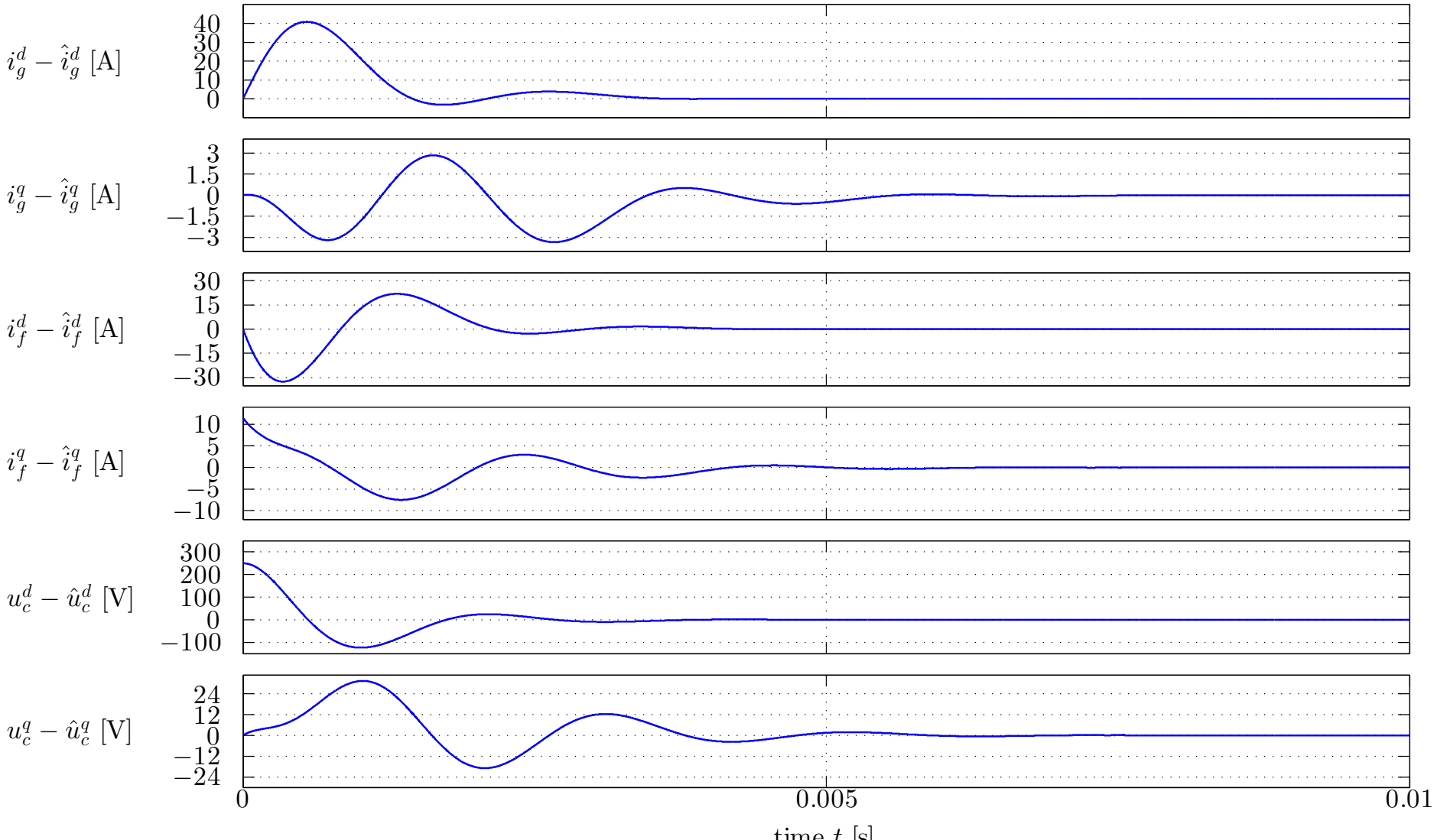
What I can offer:

- **interdisciplinary** expertise (systems & control, electrical drives, mechatronics (e.g. robots), power electronics, renewable energy systems (e.g. WTS))
- over 10 years of
  - **teaching experience** (Lectures, tutorial, practical courses, etc.; also international)
  - **research experience** (over 70 peer-reviewed publications, e.g. one monograph)
  - **project experience** with industry and research institutions (also international)
- successful in winning several **research grants** (currently over 2.5 Mio. EUR)
- **national/international network**

Outline

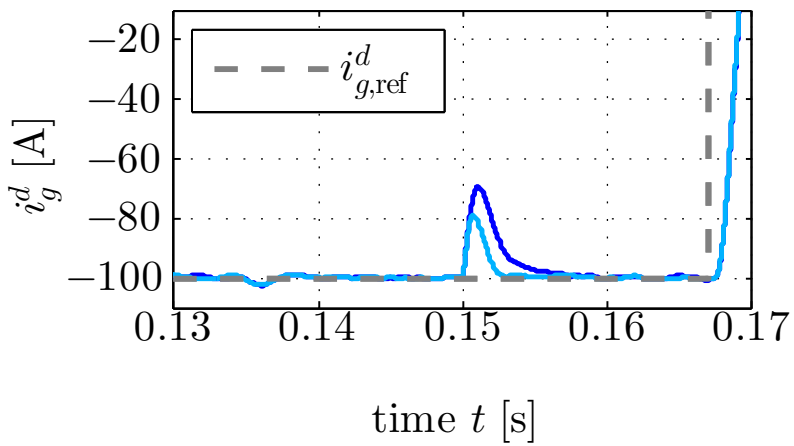
Observer SF control for GC-VSIs with LCL filter

Simulation results: Estimation error of observer for SFC with —— CDD (Zoom)

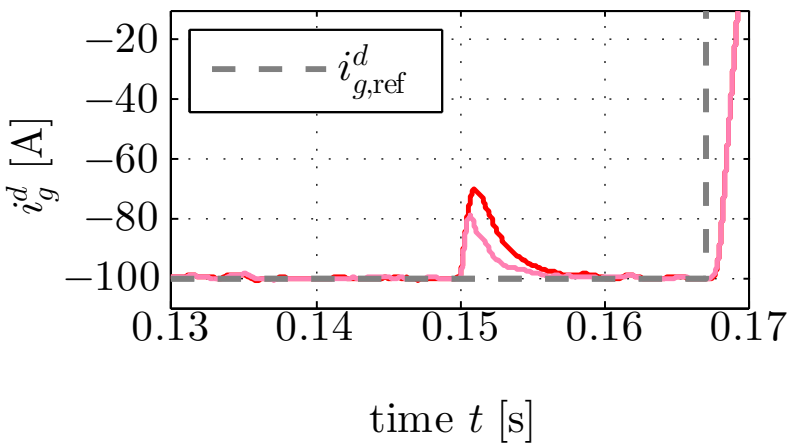


Observer SF control for GC-VSIs with LCL filter

Simulation results: Impact of disturbance feedforward compensation (DFC of grid voltage)



PI-SFC with DFC
and without DFC



I-SFC with DFC
and without DFC

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