Control of renewable energy systems

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DIE University of Santiago
Santiago de Chile, Chile

Outline

Outline

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- Technical University of Munich (TUM)
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- Munich School of Engineering (MSE)
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Technical University of Munich (TUM)

Students and staff

Students & Programs

Students	**35.979**
men	24.078
women	11.901
International students	**7.203**
1. China	1.057
2. Austria	585
3. Italy	421
4. India	415
5. Turkey	405
Programs	**154**
among these	
Bachelor	42
Master	95
English-language master and PhD	23
Programs at TUM Asia in Singapore	**5**
Newly enrolled students	**11.673**
Graduates	**7.113**

Data as of Dec. 1, 2013

TUM Members

Professors (including university hospital)	**501**
Proportion of women	16 %
New appointments 2013	**29**
Other teaching staff (including university hospital)	**6.168**
Proportion of women	33 %
Non-teaching staff (not-including university hospital)	**3.232**
Proportion of women	58 %

Technical University of Munich (TUM)

Main campuses

Departments

154 programs - 13 departments - 3 locations

Munich

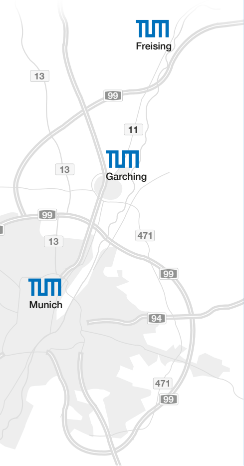
- Architecture
- Civil, Geo and Environ-mental Engineering
- Electrical, Electronic and Computer Engineering
- TUM School of Medicine
- Sport and Health Sciences
- TUM School of Education
- TUM School of Management

Garching

- Chemistry
- Informatics
- Mathematics
- Mechanical Engineering
- Physics

Freising

- TUM School of Life Sciences Weihenstephan



Locations & Networks

TUM science network

- Max Planck Institutes: Garching Martinsried Munich
- Helmholtz Zentrum München
- iwb Anwenderzentrum Augsburg
- Fraunhofer Institutes: Holzkirchen Freising

TUM locations

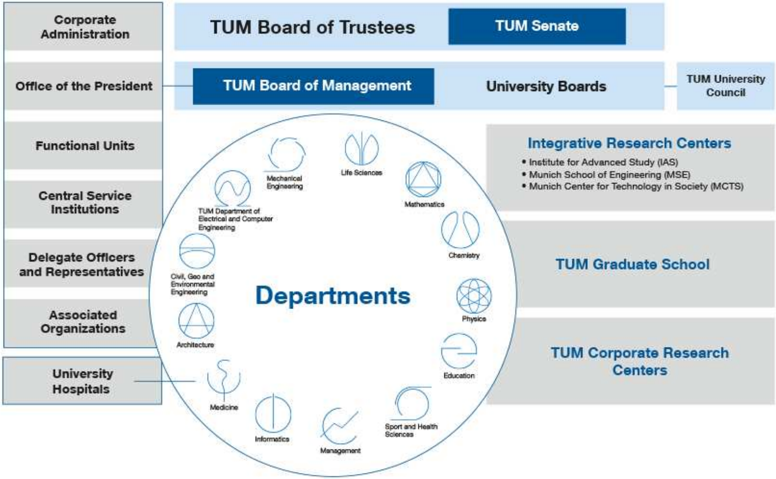
- Munich
- Garching
- Freising

- Iffeldorf
- Obernach
- Straubing
- Wettzell

- Singapore: TUM Asia
- Beijing
- Brussels
- Cairo
- Mumbai
- São Paulo

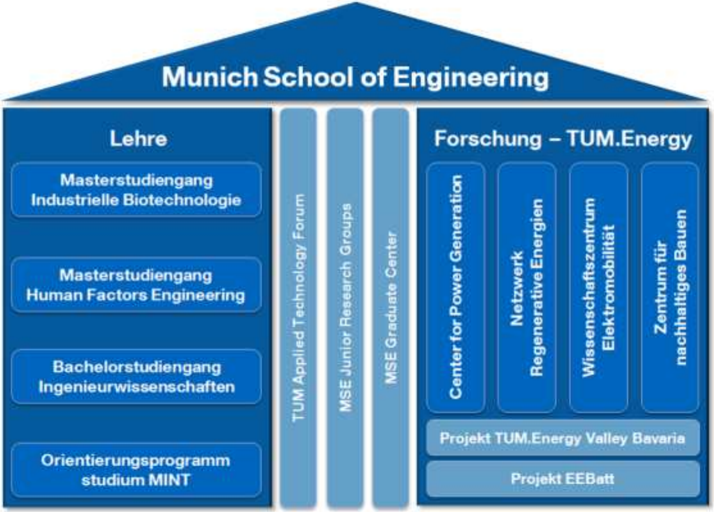
Technical University of Munich (TUM)

Organigram



Munich School of Engineering (MSE)

Integrative research center (Organigram)



Munich School of Engineering (MSE)

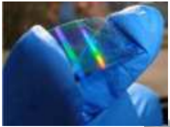
Recent research foci

CPG Center for Power Generation

- flexible power plant technologies
- synthetic energy carriers
- technologies for energy storage
- energy studies and concepts
- solarthermal power plants

NRG Network for Renewable Energy

- carbon neutral energy generation
- novel energy materials
- conversion of raw materials to energy sources
- local energy storage



TUM.Energy

- interdisciplinary development of electric vehicles
- investigation of mobility behavior
- development of new mobility concept

Science Center for Electromobility

- sustainable urban development
- sustainable buildings
- energy optimized building envelopes
- energy efficient building technology

ENPB Center for Sustainable Building

Group “Control of renewable energy systems (CRES)”

Team


H. Eldeeb, M.Sc.
(CRES,09/2015)


C. Dirscherl, M.Sc.
(CRES,01/2014)


C. Hackl, Dr.-Ing.
(CRES,01/2014)


J. Kullick, M.Sc.
(CRES,10/2015)


K. Schechner, M.Sc.
(CRES,01/2014)


Z. Zhang, M.Sc.
(CRES/EAL,07/2015)

External PhD candidates


S. Krüner, M.Sc.
(SINNPower,11/2015)


A. Birda, M.Sc.
(BMW,04/2016)

. . . and collaborations with EAL (Prof. Kennel)


F. Bauer, M.Sc.
(EAL)


M. Abdelrahem,
M.Sc. (EAL)


A. Ayad,
M.Sc. (EAL)

Group “Control of renewable energy systems (CRES)”

Research projects

Classical wind turbine systems

Focus: Efficiency and reliability

Airborne wind energy systems

Focus: Fault-tolerant control

Small-scale wind turbines

Focus: Use of RSMs ($\leqslant$ 50 kW)

Wave converters (SINN Power)

Focus: Efficiency and reliability

Geothermal power systems

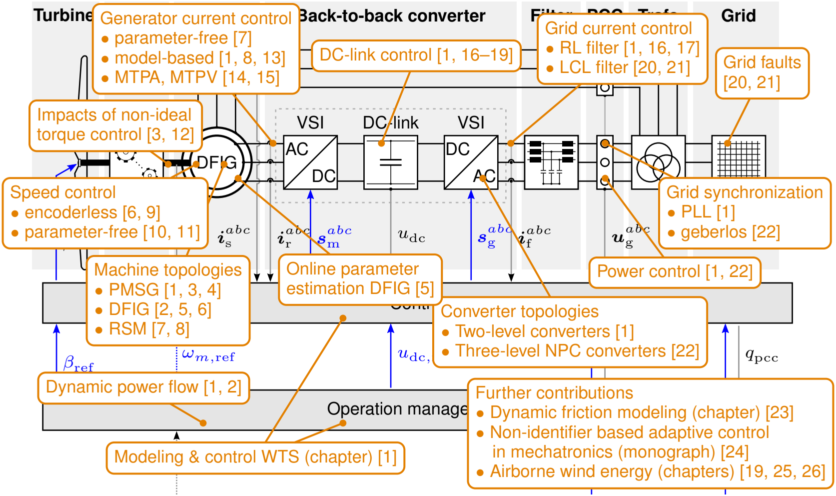
Focus: Fault-tolerant control

Electric vehicles (BMW)

Focus: Optimal control

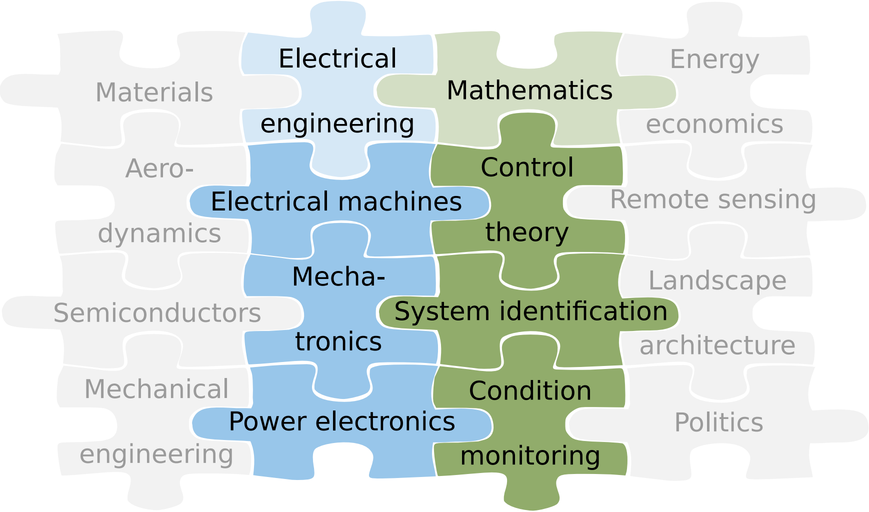
Group “Control of renewable energy systems (CRES)”

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



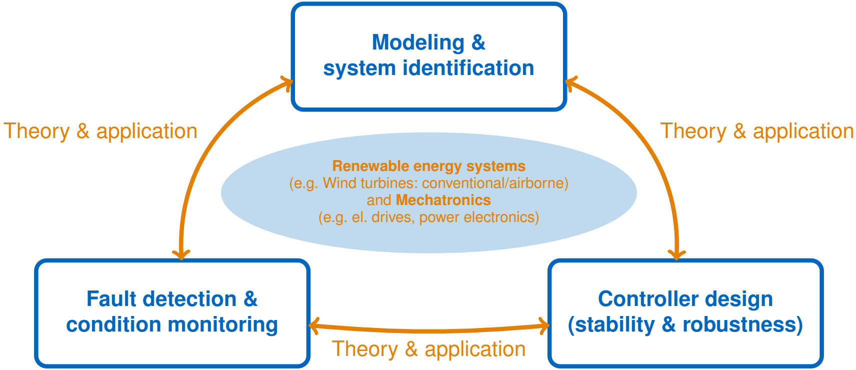
Group “Control of renewable energy systems (CRES)”

Energy Research: Necessity of interdisciplinary approach



Group “Control of renewable energy systems (CRES)”

Research concept



Group “Control of renewable energy systems (CRES)”

Laboratory setup

Reluctance and Permanent-magnet SMs

Electrically-excited SM and doubly-fed IM

Real-time system and VSIs

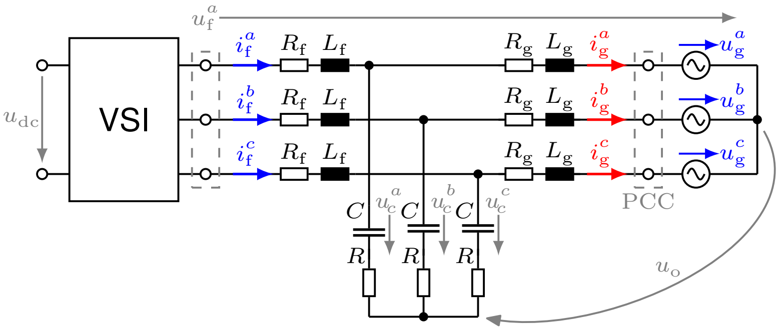
Outline

2 State feedback (SF) control with observer for grid-connected voltage source inverters (GC-VSIs) with LCL filter

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

SF control with observer for GC-VSIs with LCL filter

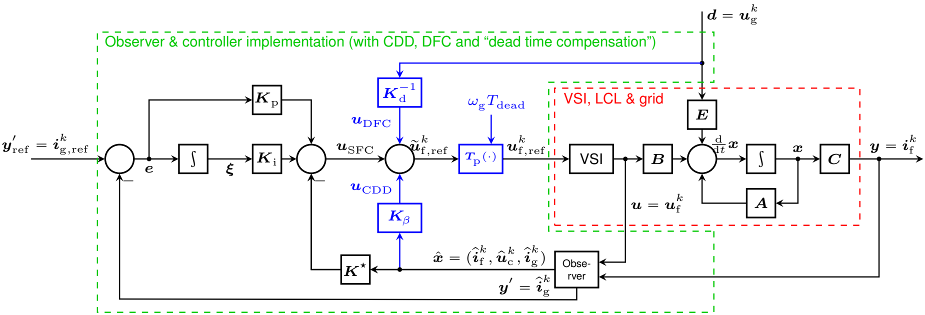
Electrical network and problem statement



- Control of grid currents $\boldsymbol{i}_g^{abc}$ (Active and reactive power)
- Measurement of inverter-side currents $\boldsymbol{i}_f^{abc}$ and grid voltage $\boldsymbol{u}_g^{abc}$
- active damping of resonance frequency $\omega_{res} = \sqrt{\frac{L_f + L_g}{C L_f L_g}}$ of LCL filter

SF control with observer for GC-VSIs with LCL filter

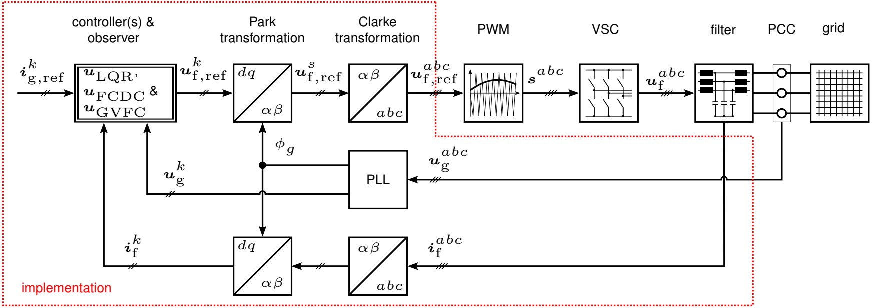
Block diagram of overall control structure



- State feedback controller (SFC): $u_{SFC}(t) = K^\star \hat{x}(t) + K_p e(t) + K_i \int_0^t e(\tau)\,d\tau$
- Luenberger Observer for state estimation $\hat{x}(t)$ (only using i_f^k, u_f^k & u_g^k)
- Disturbance feedforward comp. (DFC): $u_{DFC}(t) = K_d^{-1} u_g^k(t)$ (u_g^k from PLL)
- Current dynamics decoupling (CDD): $u_{CDD}(t) = K_\beta \hat{x}(t)$
- Dead time compensation: $u^k_{f,ref}(t) = T_p(\omega_g T_{dead}) \tilde{u}^k_{f,ref}(t)$ (ω_g from PLL)

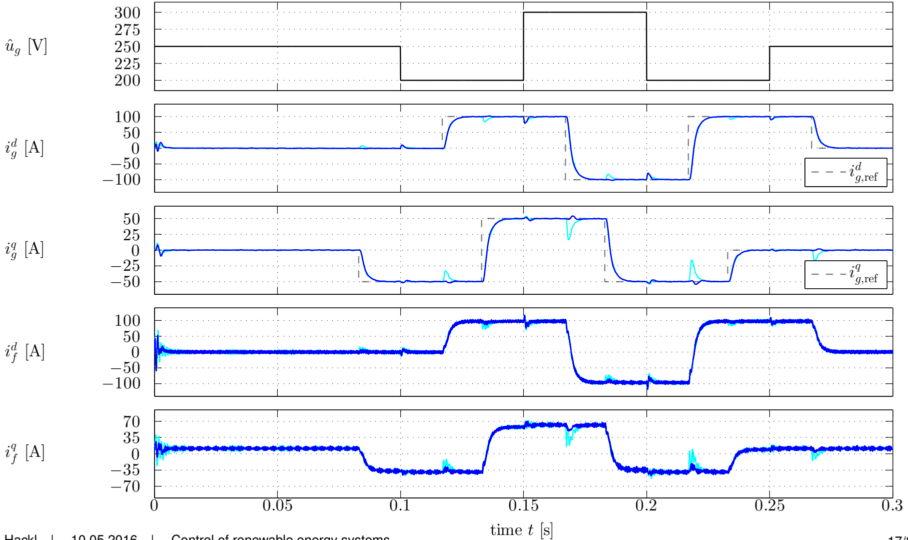
SF control with observer for GC-VSIs with LCL filter

Implementation of controller and observer



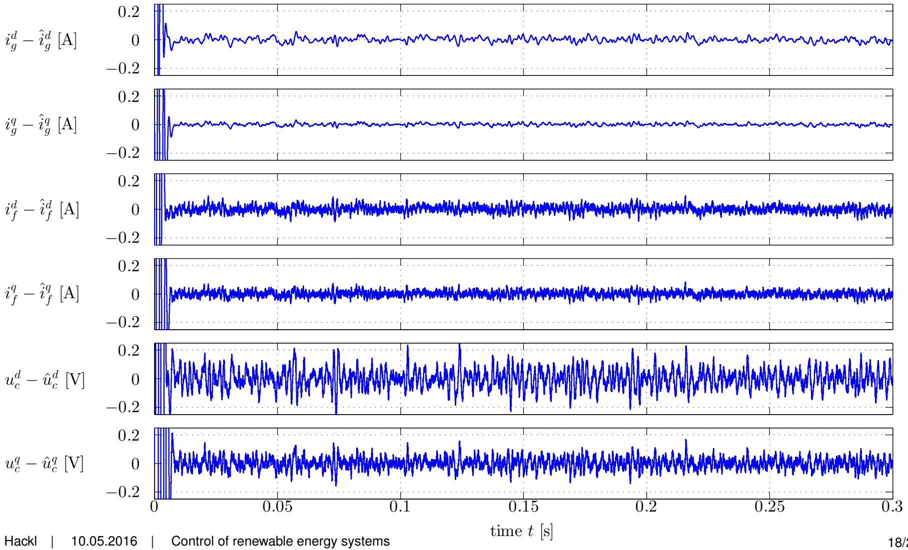
SF control with observer for GC-VSIs with LCL filter

Simulation results: Control performance of SFC with —— and without —— CDD



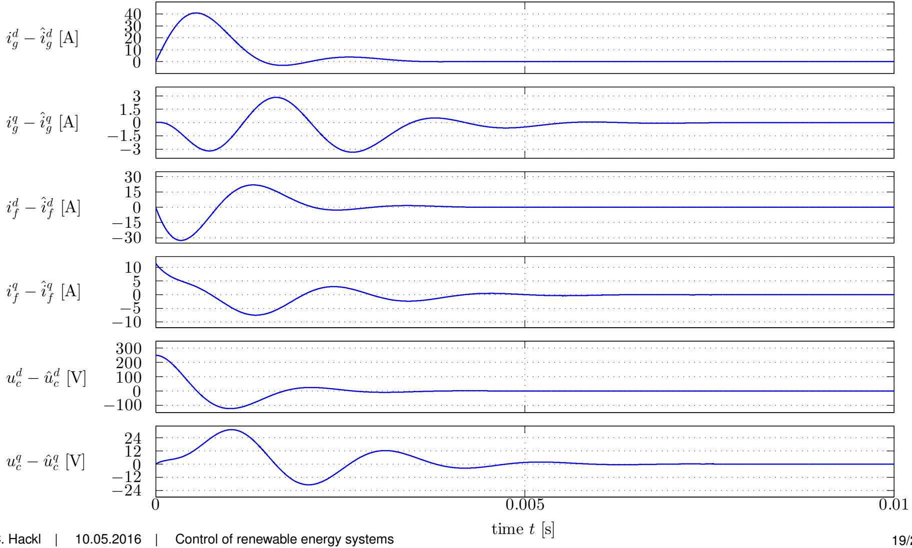
SF control with observer for GC-VSIs with LCL filter

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



SF control with observer for GC-VSIs with LCL filter

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



Outline

3 Conclusion

Conclusion

Control

- is essential and achieves active damping (*state space* analysis very powerful)
- allows to reduce number of installed sensors in combination with observer (cheaper)
- LQR with stability margin guarantees optimal operation and increased robustness
- Disturbance feedforward compensation and current decoupling additionally improve control performance

Future challenges for "Renewable Energy Systems" (see also [27])

- Reduction of levelized costs of Energy
  $\Longrightarrow$ "Energiewende" economically feasible?
- Improving reliability and increasing fault tolerance
  (in particular, controls and electrical sub-system are fault-prone)
- Flexible and robust grid connection
- Emerging technologies (e.g. new generator / converter topologies)

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