Forschergruppe "Control of renewable energy systems (CRES)"

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Technische Universität München (TUM)

24.11.2015

BWM, München

Team und Expertise

CRES Team

H. Eldeeb, M.Sc.
(CRES/EAL,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))

Externe Doktoranden bzw. Kollaborationen

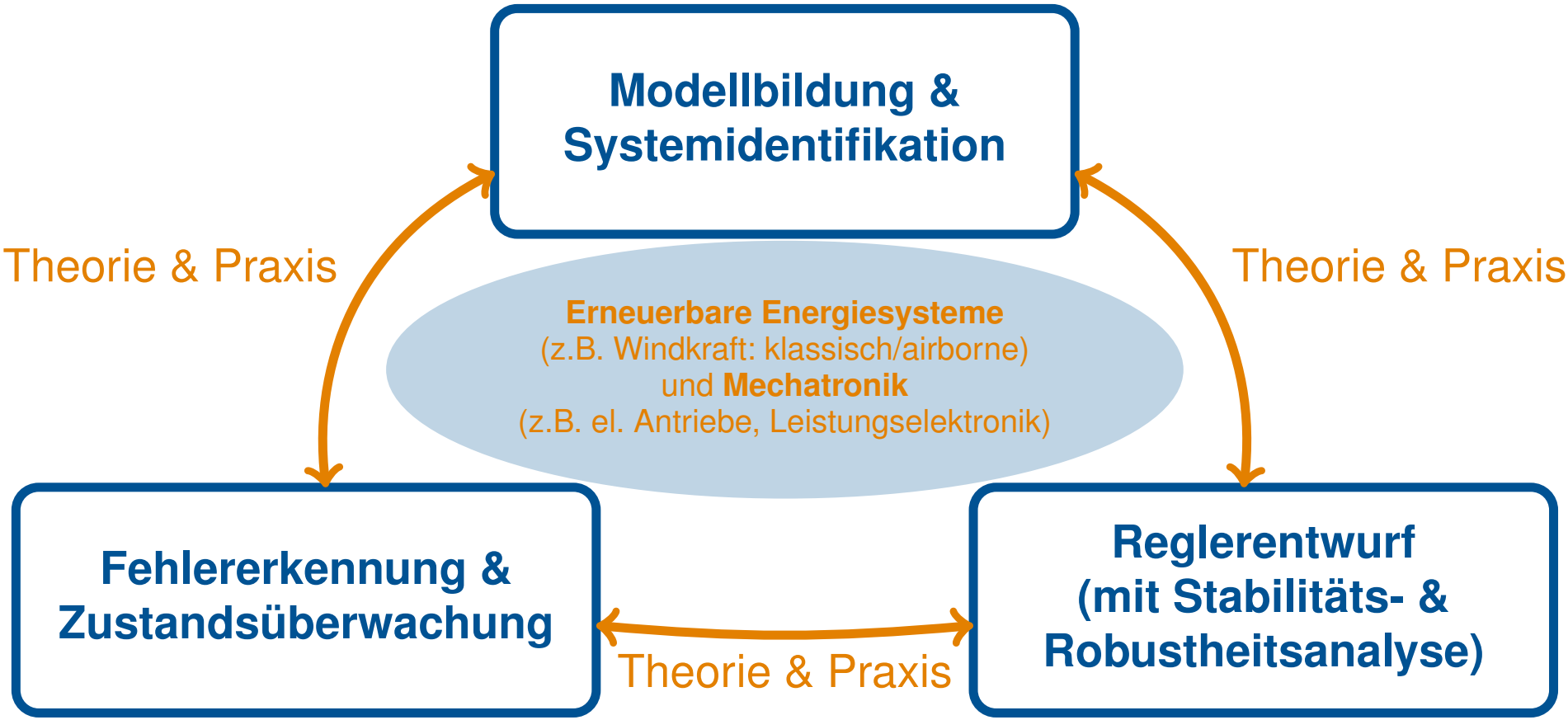
S. Krüner, M.Sc.
(SINN Power GmbH)

F. Bauer, M.Sc.
(EAL)

M. Abdelrahem,
M.Sc. (EAL)

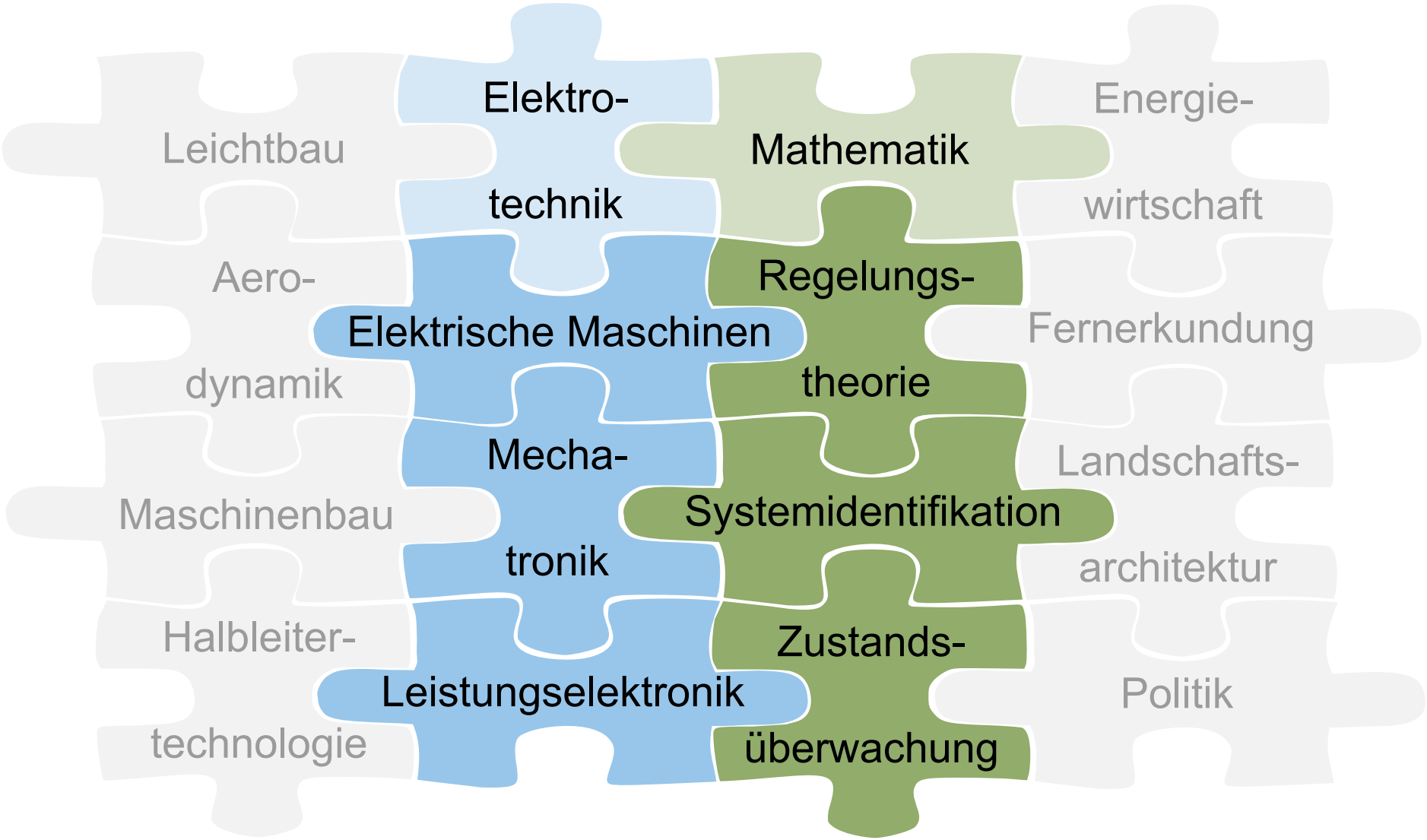
Team und Expertise

Forschungskonzept



Team und Expertise

Interdisziplinärer Ansatz



Forschung

Forschungsschwerpunkt: Modellierung und Regelung von **Windkraftanlagen (WKA)**

Klassische Windkraftanlagen

$\Longrightarrow$ Ziel: Erhöhen der Zuverlässigkeit

Flugwindkraftanlagen

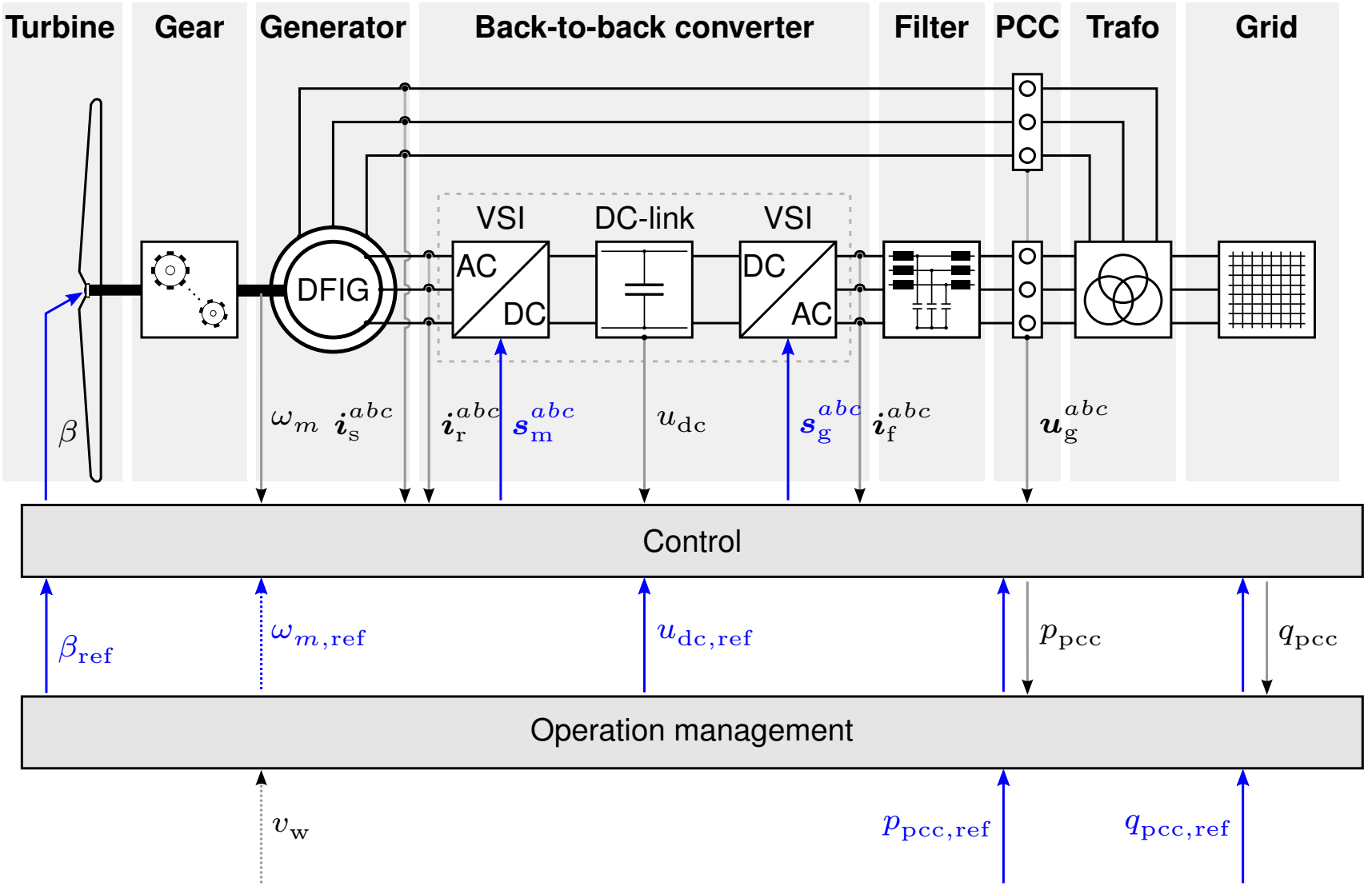
$\Longrightarrow$ Ziel: Fehlertolerante Regelung

Kleinwindkraftanlagen ($\leqslant$ 50 kW)

$\Longrightarrow$ Ziel: Einsatz von Reluktanz-Synchrongeneratoren

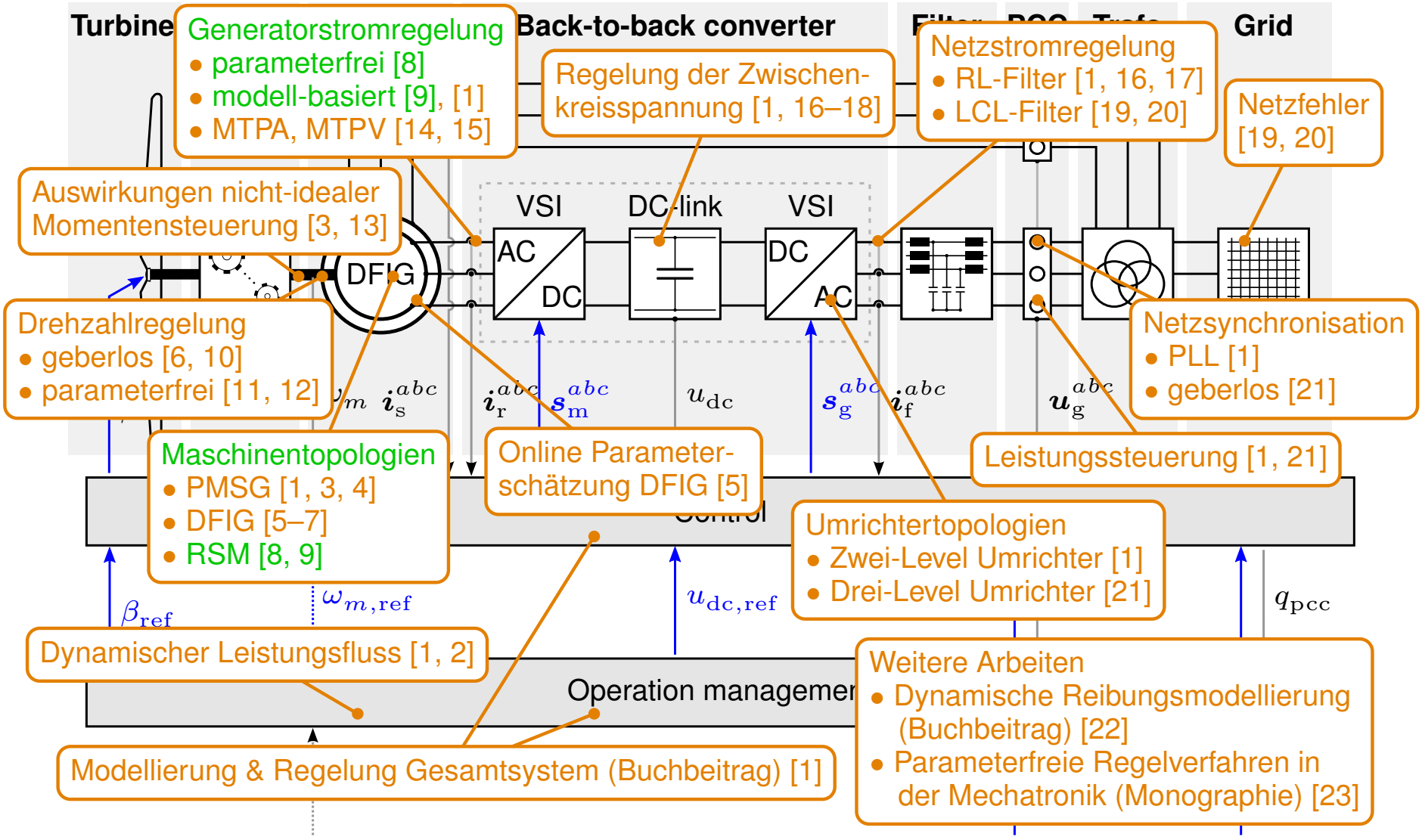
Forschung

Forschungsblickwinkel: **Elektrische** Komponenten von Windkraftanlagen



Forschung

Publikationen



Forschung

Laufende Drittmittelprojekte

Computationally-efficient direct MPC for WTS (172.000 EUR)

DFG Deutsche Forschungsgemeinschaft

Robust and fault-tolerant low-level control of the electrical drive system (250.000 EUR)

AWESCO Airborne Wind Energy System Modelling, Control & Optimisation

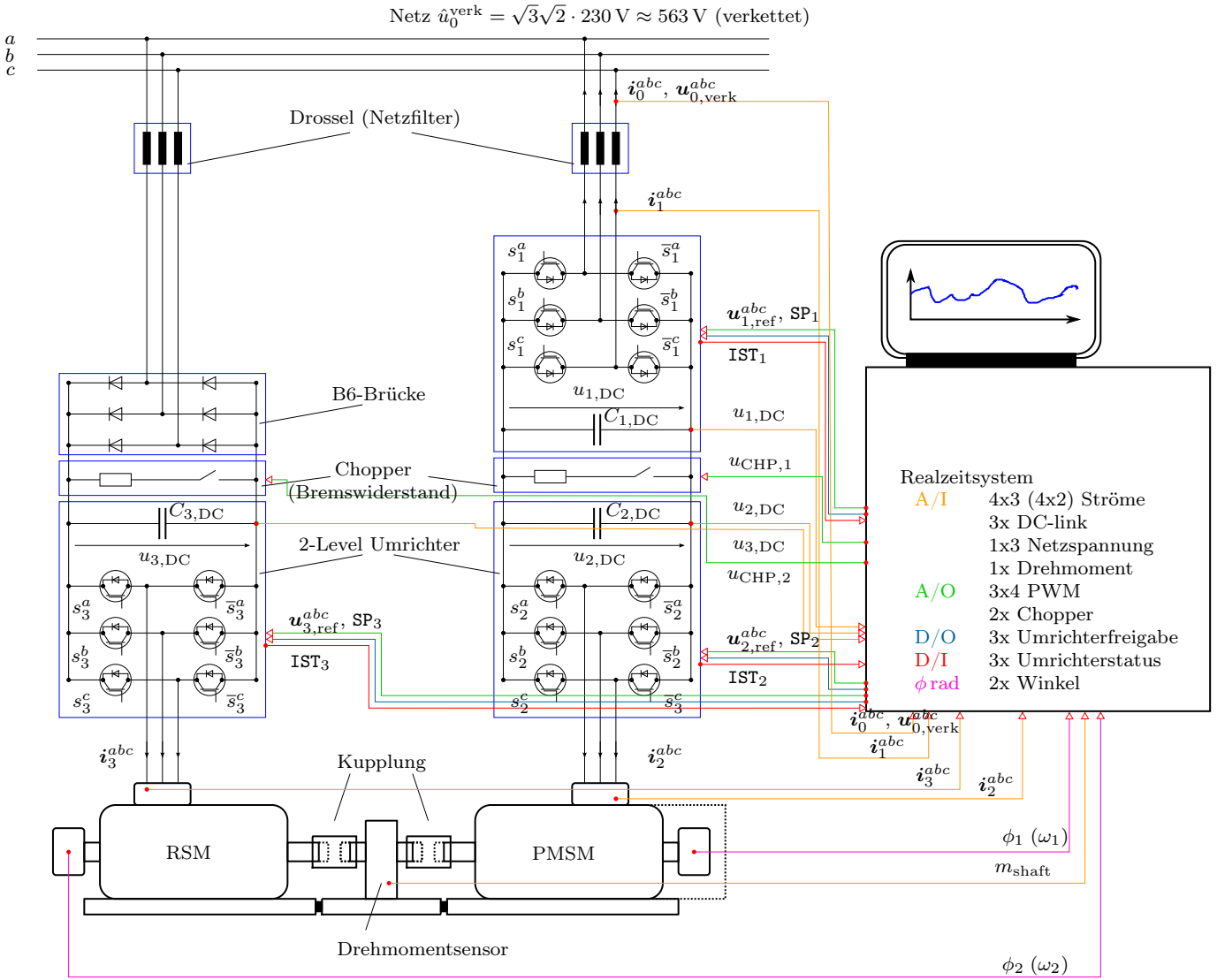
Klein-Windkraftanlagen mit Reluktanz-Synchrongenerator (20.000 EUR)

Bund der Freunde der Technischen Universität München e.V.

- DFG-Projekt (PI mit Prof. Kennel)
  "*Computationally-efficient direct MPC of 3L-NPC back-to-back converters for WTS with PMSGs*"
- EU H2020 ITN-Projekt (PI mit Prof. Kennel)
  "*Airborne Wind Energy System Modelling, Control and Optimisation (AWESCO)*"
- Bund der Freunde der TUM e.V. Projekt
  "*Klein-Windkraftanlagen mit effizienter und kostengünstiger Generatortopologie für Micro-Grids – Eine Voruntersuchung*"

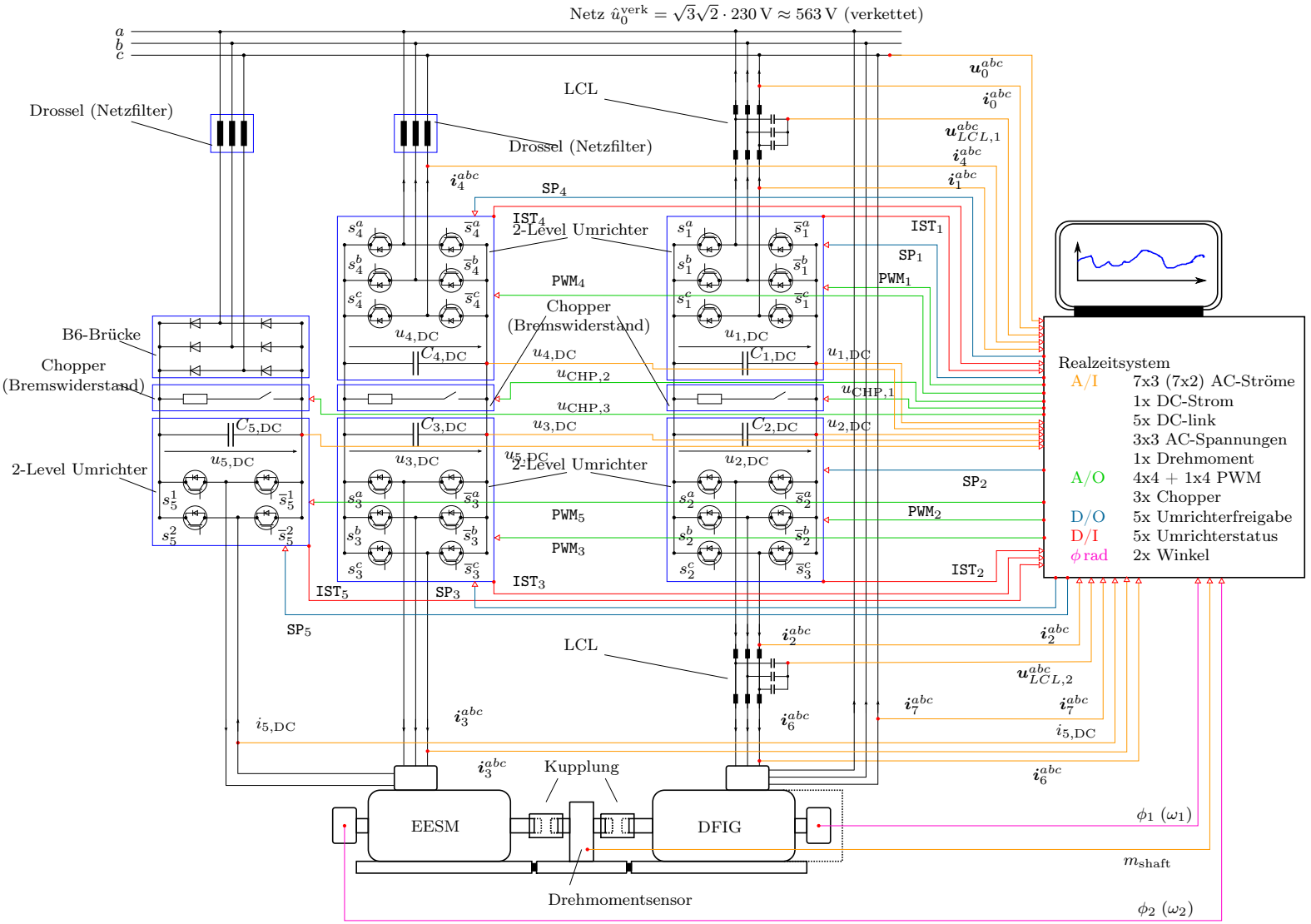
Laboraufbau

Aufbau 1: Reluktanz-Synchronmaschine und Permanentmagnet-Synchronmaschine



Laboraufbau

Aufbau 2: Fremd-erregte Synchronmaschine und doppelt-gespeiste Asynchronmaschine



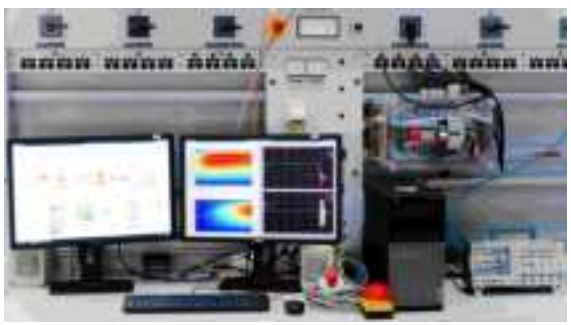
Laboraufbau

Laboraufbau (aktueller Stand)

Reluktanz- und Permanentmagnet-Synchronmaschine

Realzeitsystem und Umrichter

Host PC und Sicherheitsbox



Doppelt-gespeiste ASM

Literaturliste I

[1] C. Dirscherl, C. Hackl, and K. Schechner, “Modellierung und Regelung von modernen Windkraftanlagen: Eine Einführung *(available at the authors upon request)*,” in *Elektrische Antriebe – Regelung von Antriebssystemen* (D. Schröder, ed.), ch. 24, pp. 1540–1613, Springer-Verlag, 2015.

[2] C. Dirscherl and C. M. Hackl, “Dynamic power flow in wind turbine systems with doubly-fed induction generator,” *IEEE Transactions on energy conversion (in preparation)*, 2015.

[3] C. M. Hackl and K. Schechner, “Non-ideal torque control of wind turbine systems: Impacts on annual energy production,” in *Proceedings of the IEEE International Energy Conference (submitted)*, 2016.

[4] Z. Zhang, C. Hackl, T. Sun, and R. Kennel, “Computationally efficient DMPC for three-level NPC back-to-back converters in wind turbine systems with PMSG,” *submitted to IEEE Transactions on Power Electronics*, 2015.

[5] M. Abdelrahem, C. M. Hackl, and R. Kennel, “Application of extended Kalman filter to parameter estimation of doubly-fed induction generators in variable-speed wind turbine systems,” in *Proceedings of the 5th International Conference on Clean Electrical Power*, pp. 236–243, 2015.

[6] M. Abdelrahem, C. M. Hackl, and R. Kennel, “Sensorless control of doubly-fed induction generators in variable-speed wind turbine systems,” in *Proceedings of the 5th International Conference on Clean Electrical Power*, pp. 423–430, 2015.

[7] C. Dirscherl and C. M. Hackl, “Dynamic power flow in wind turbine systems with doubly-fed induction generator,” in *submitted to 2016 IEEE Inernational Energy Conference*, 2016.

[8] C. M. Hackl, “Current PI-funnel control with anti-windup for synchronous machines,” in *Proceedings of the 54th IEEE Conference on Decision and Control*, p. (to be published), 2015.

[9] C. M. Hackl, M. J. Kamper, J. Kullick, and J. Mitchell, “Nonlinear PI current control of reluctance synchronous machines,” *IEEE Transactions on Industrial Electronics (submitted)*, 2015.

Literaturliste II

[10] Z. Zhang, C. Hackl, F. Wang, Z. Chen, and R. Kennel, “Encoderless model predictive control of back-to-back converter direct-drive permanent-magnet synchronous generator wind turbine systems,” in *Proceedings of 15th European Conference on Power Electronics and Applications*, pp. 1–10, 2013.

[11] C. M. Hackl, “Funnel control for wind turbine systems,” in *Proceedings of the 2014 IEEE International Conference on Control Applications*, pp. 1377–1382, 2014.

[12] C. M. Hackl, “Speed funnel control with disturbance observer for wind turbine systems with elastic shaft,” in *Proceedings of the 54th IEEE Conference on Decision and Control*, p. (to be published), 2015.

[13] C. M. Hackl and K. Schechner, “Non-ideal torque control in wind turbine systems: Causes and impacts,” in *Proceedings of the 5$^{\text{th}}$ MSE-Kolloquium on “Innovations for Energy Systems, Mobility, Buildings and Materials”*, 2015.

[14] J. Kullick, “Simulation and control of a small-scale wind turbine system with reluctance synchronous generator,” Master’s thesis, Technische Universität München, MSE Research Group "Control of renewable energy systems", 2015.

[15] L. Horlbeck, M. Lienkamp, and C. Hackl, “Analytical solution for the MTPV hyperbola including the stator resistance,” in *Proceedings of the IEEE International Conference on Industrial Technology (submitted)*, 2016.

[16] C. Dirscherl, C. Hackl, and K. Schechner, “Explicit model predictive control with disturbance observer for grid-connected voltage source power converters,” in *Proceedings of the 2015 IEEE International Conference on Industrial Technology*, pp. 999–1006, 2015.

Literaturliste III

[17] C. Dirscherl, C. M. Hackl, and K. Schechner, “Pole-placement based nonlinear state-feedback control of the DC-link voltage in grid-connected voltage source power converters: A preliminary study,” in *Proceedings of the 2015 IEEE International Conference on Control Applications*, p. (to be published), 2015.

[18] F. Bauer, C. M. Hackl, and K. Schechner, “DC-link control for airborne wind energy systems during pumping mode,” in *Proceedings of the Airborne Wind Energy Conference 2015*, 2015.

[19] C. M. Hackl, “MPC with analytical solution and integral error feedback for LTI MIMO systems and its application to current control of grid-connected power converters with LCL-filter,” in *Proceedings of the 3rd Symposium on Predictive Control of Electrical Drives and Power Electronics (PRECEDE 2015)*, p. (to be published), 2015.

[20] C. Dirscherl, J. Fessler, C. M. Hackl, and H. Ipach, “State-feedback controller and observer design for grid-connected voltage source power converters with LCL-filter,” in *Proceedings of the 2015 IEEE International Conference on Control Applications*, p. (to be published), 2015.

[21] Z. Zhang, H. Xu, M. Xue, Z. Chen, T. Sun, R. Kennel, and C. Hackl, “Predictive control with novel virtual flux estimation for back-to-back power converters,” *IEEE Transactions on Industrial Electronics*, vol. 62, no. 5, pp. 2823–2834, 2015.

[22] C. M. Hackl, “Dynamische Reibungsmodellierung: Das Lund-Grenoble (LuGre) Reibmodell *(available at the authors upon request)*,” in *Elektrische Antriebe – Regelung von Antriebssystemen* (D. Schröder, ed.), ch. 25, pp. 1615–1657, Springer-Verlag, 2015.

[23] C. M. Hackl, *Non-identifier based adaptive control in mechatronics: Theory and Application*. Lecture Notes in Control and Information Sciences, Berlin: Springer-Verlag, 2015 (accepted; final version in preparation).