Funnel Control in der Mechatronik

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Ringvorlesung Magnetics 4 Freaks
Hochschule Heilbronn, Künzelsau

Gliederung

Vorstellung

Forschergruppe “Control of renewable energy systems (CRES)”

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

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

C. Hackl, Dr.-Ing.
(Head of CRES)

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

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

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

Klassische Windkraftanlagen

Ziel: Erhöhen der Zuverlässigkeit

Flugwindkraftanlagen

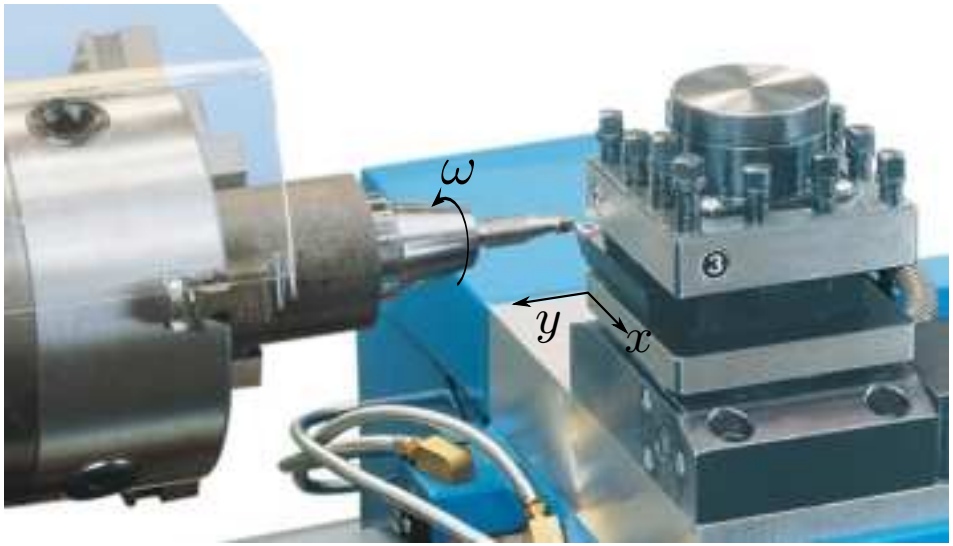
Ziel: Fehlertolerante Regelung

Kleinwindkraftanlagen

Ziel: Einsatz von RSM ($\leqslant 50\,\mathrm{kW}$)

Problemstellung und Motivation

Folgewertregelung unter Last (z.B. Drehmaschine)



(http://www.knuth.de)

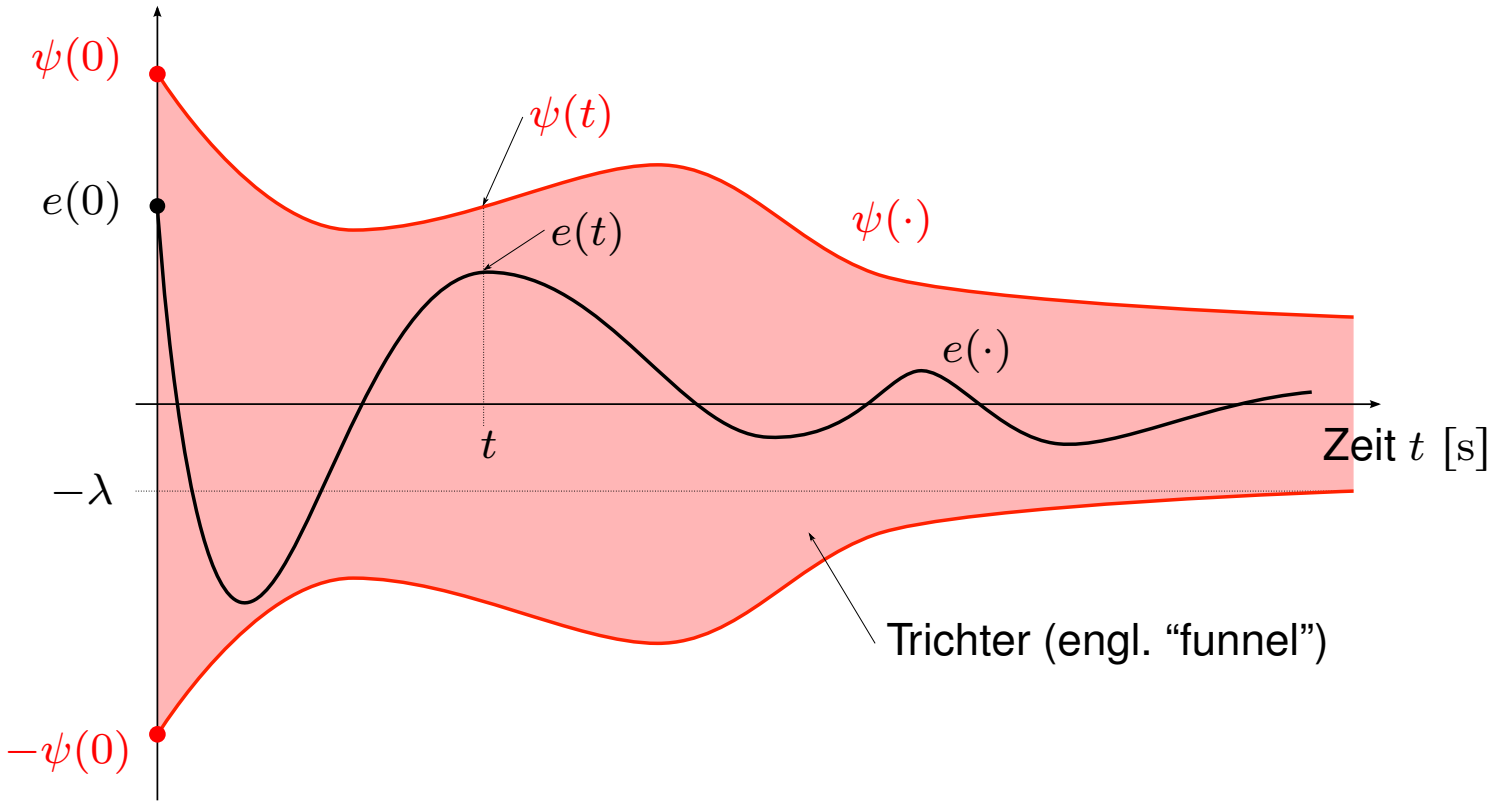
- Problemstellung
  - Sollgrößen $(\omega_{\mathrm{ref}}, x_{\mathrm{ref}}, y_{\mathrm{ref}}) \colon \mathbb{R}_{>0} \to \mathbb{R}^3$
  - Präzise Positions- und Geschwindigkeitsregelung, z.B. für gegebenes $\lambda > 0$

$$\boxed{\forall\, t \geqslant t_0 \colon \qquad |e(t)| = |y_{\mathrm{ref}}(t) - y(t)| \leqslant \lambda.}$$

- Herausforderungen
  - Nichtlineare Effekte (z.B. Stellgrößenbeschränkungen, Reibung)
  - Störgrößen und Systemparameter unbekannt (oder nur grob bekannt)

Funnel Regler für Folgewertprobleme

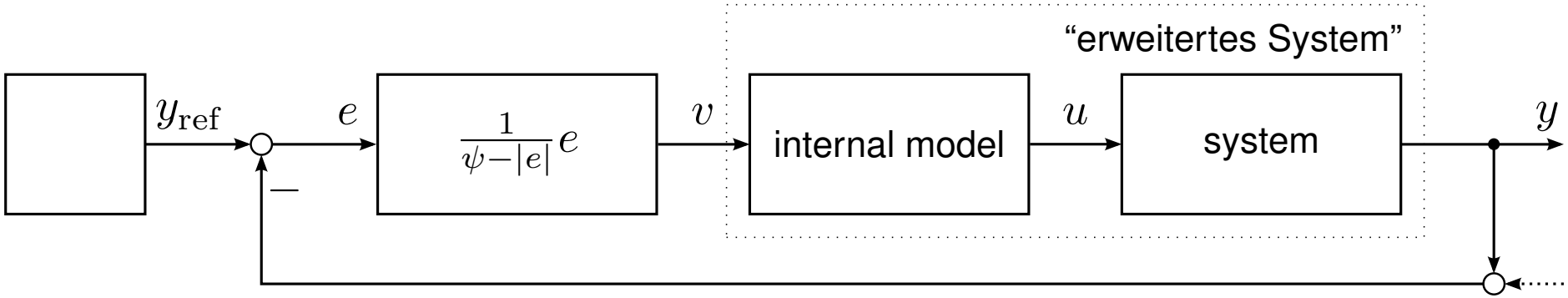
Regelziel und Regelgesetz [1]



$$u(t) = k(t)\big(\underbrace{y_{\mathrm{ref}}(t) - y(t)}_{=:e(t)}\big) \quad \text{wobei} \quad k(t) = \frac{1}{\psi(t) - |e(t)|}$$

Funnel Regler für Folgewertprobleme

Asymptotische Genauigkeit mithilfe von Internen Modellen [2–5]



Beispiel (Interne Modelle $\Longrightarrow \lim_{t\to\infty} e(t) = 0$)

- Konstante Referenz, z.B. $y_{\text{ref}}(t) = c > 0$:

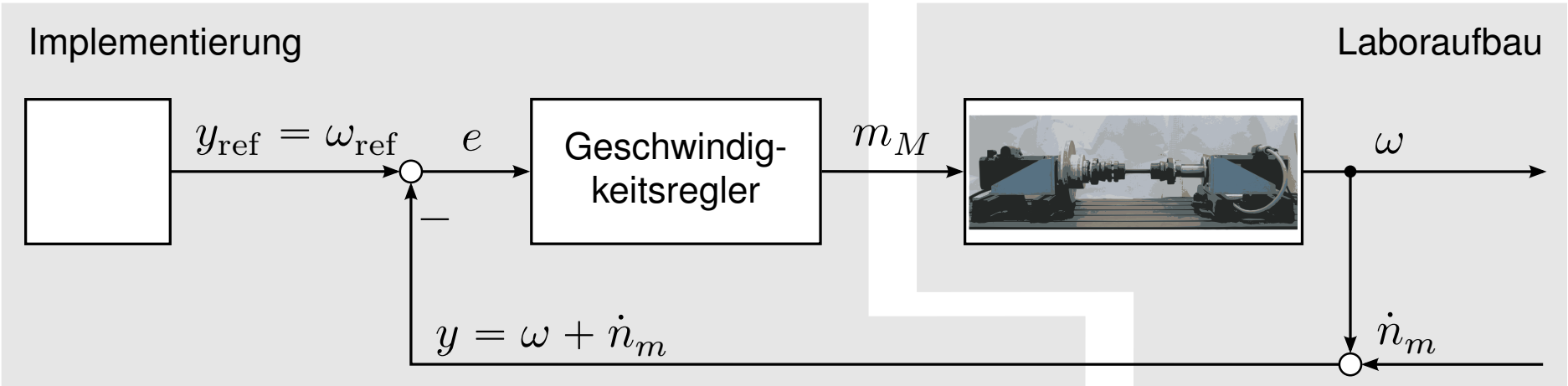
$$F_{IM}(s) = k_P + \frac{k_I}{s} = \frac{k_P\, s + k_I}{s}, \qquad k_P,\, k_I > 0$$

- Sinusförmige Referenz, z.B. $y_{\text{ref}}(t) = \sin(2\pi f_0 t)$:

$$F_{IM}(s) = \frac{(s+k_C)^2}{s^2+(2\pi f_0)^2}, \qquad k_C > 0$$

Geschwindigkeitsregelung von Industrieantrieben

Implementierung der Geschwindigkeitsregelung [6, 7]



- Standard PI Regler

$$m_M(t) = k_P\, e(t) + k_I \int_0^t e(\tau)\,\mathrm{d}\tau$$

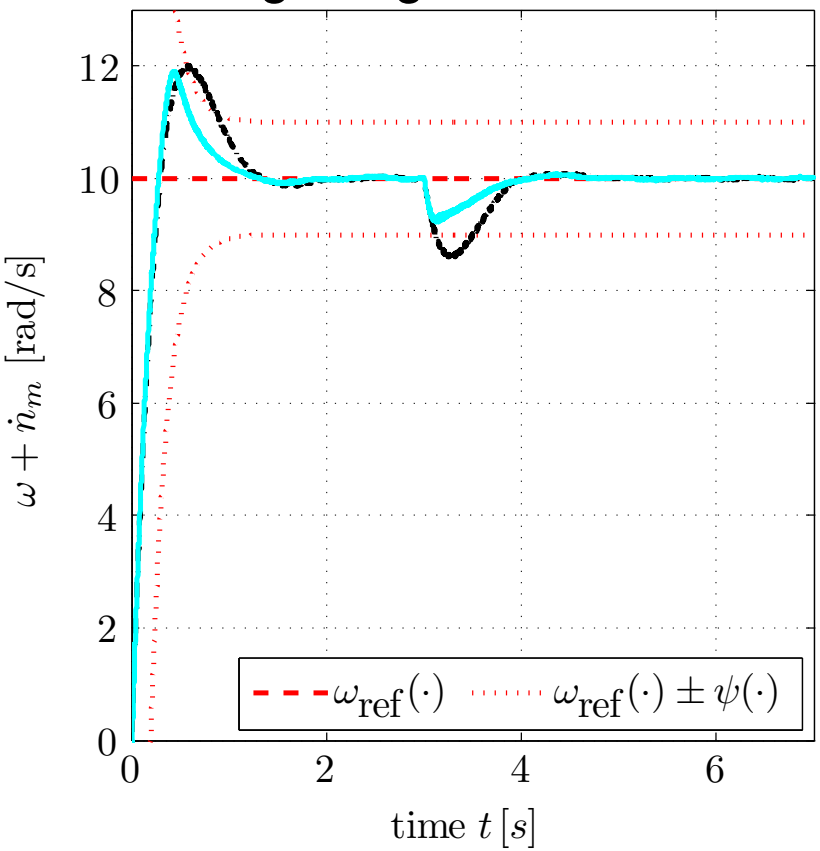
- PI-Funnel Regler

$$m_M(t) = k(t)\, e(t) + k_I \int_0^t k(\tau) e(\tau)\,\mathrm{d}\tau \qquad \text{mit} \qquad k(t) = \frac{1}{\psi(t) - |e(t)|}$$

Geschwindigkeitsregelung von Industrieantrieben

Messergebnisse zur Geschwindigkeitsregelung [6, 7]

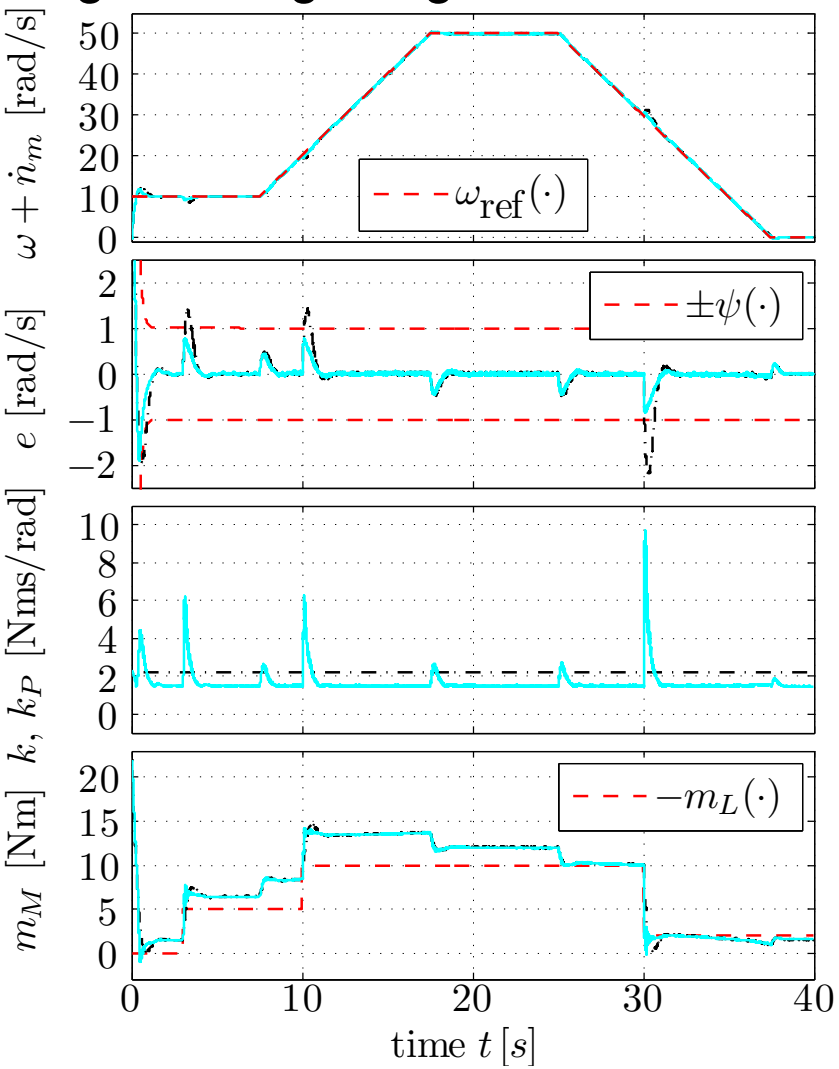
Festwertregelung



PI-Funnel Regler

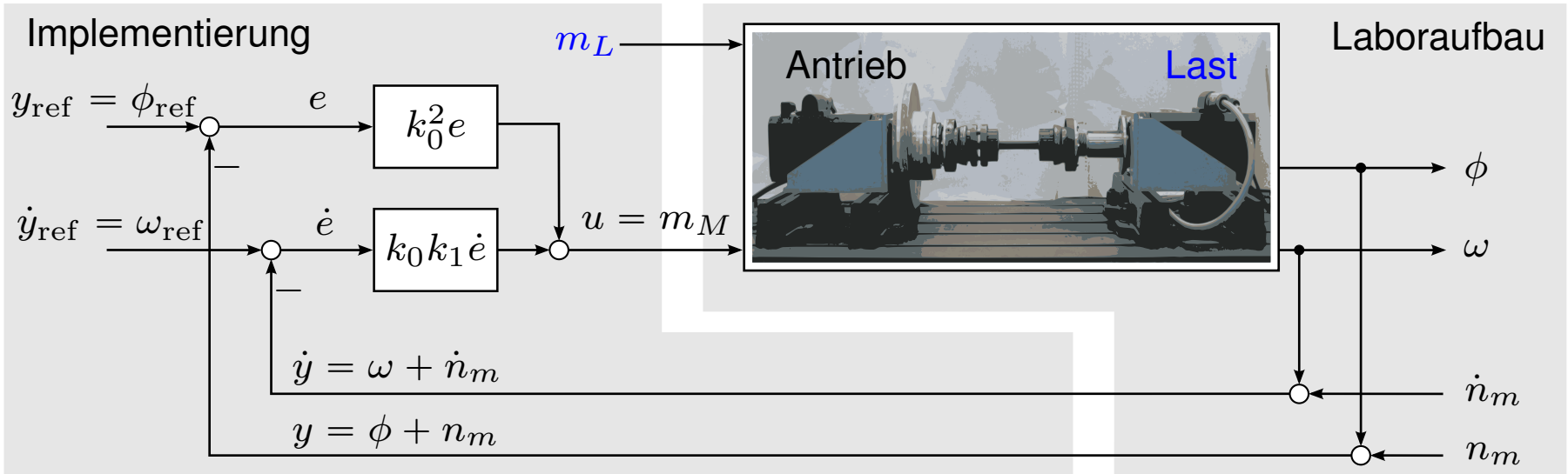
PI Regler

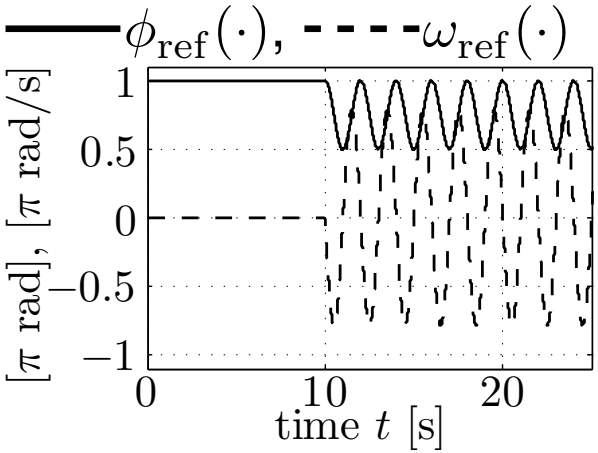
Folgewertregelung

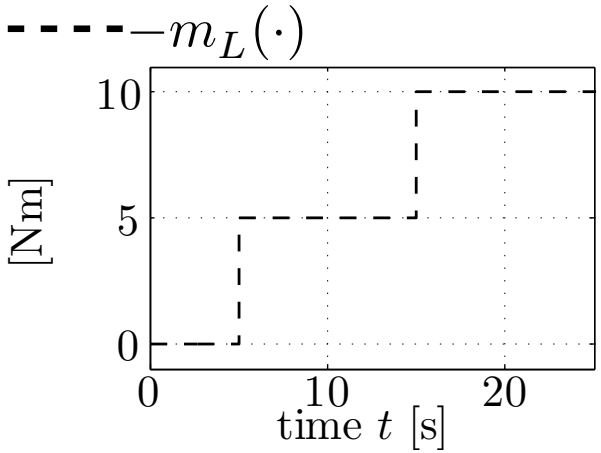


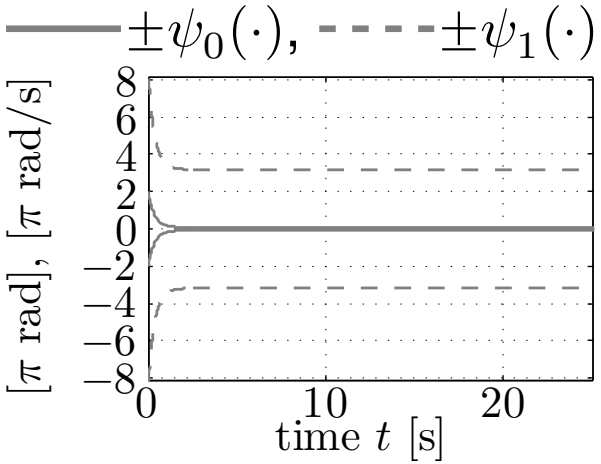
Positionsregelung von Industrieantrieben

Implementierung der Positionsregler [5]



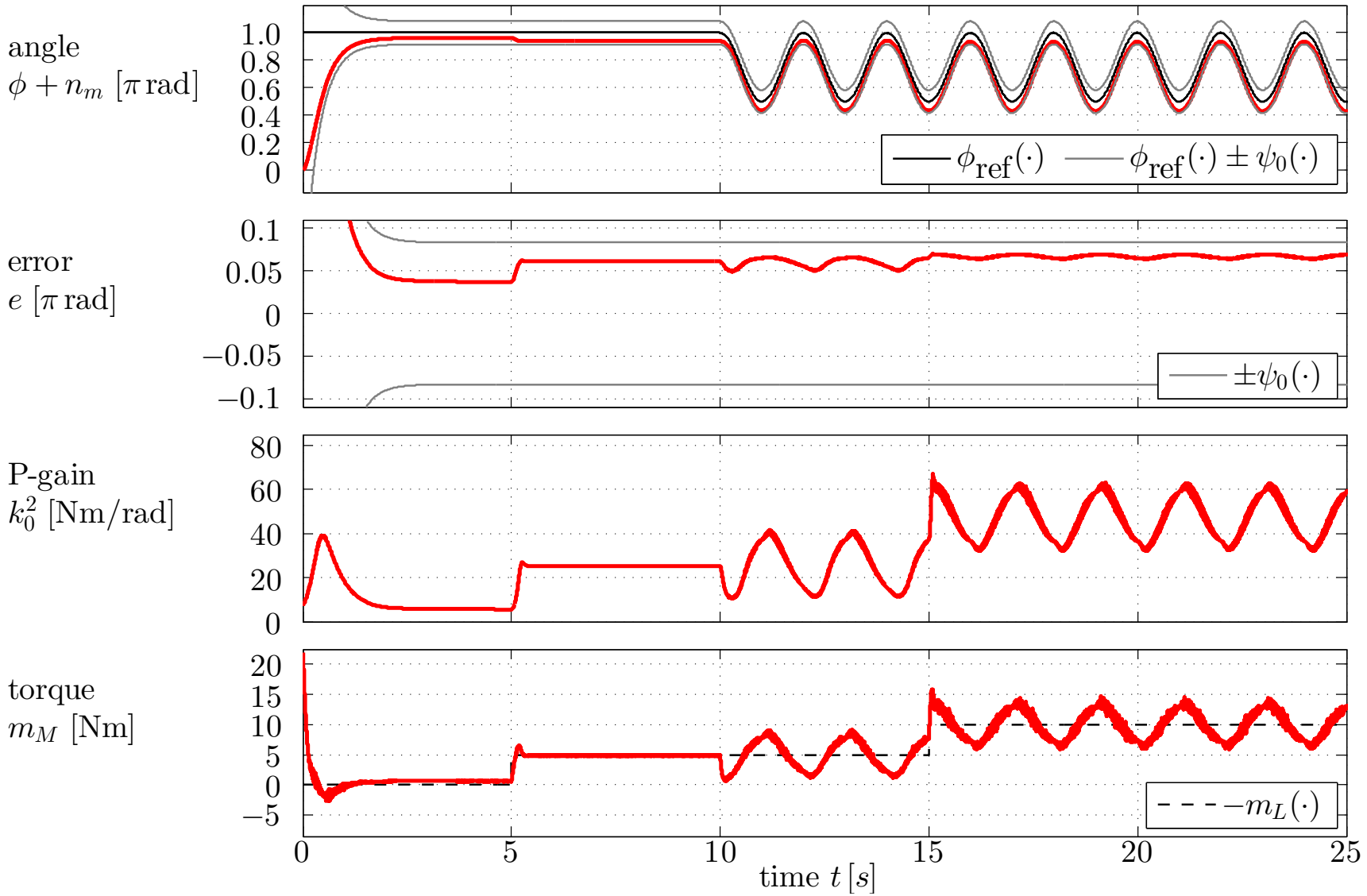






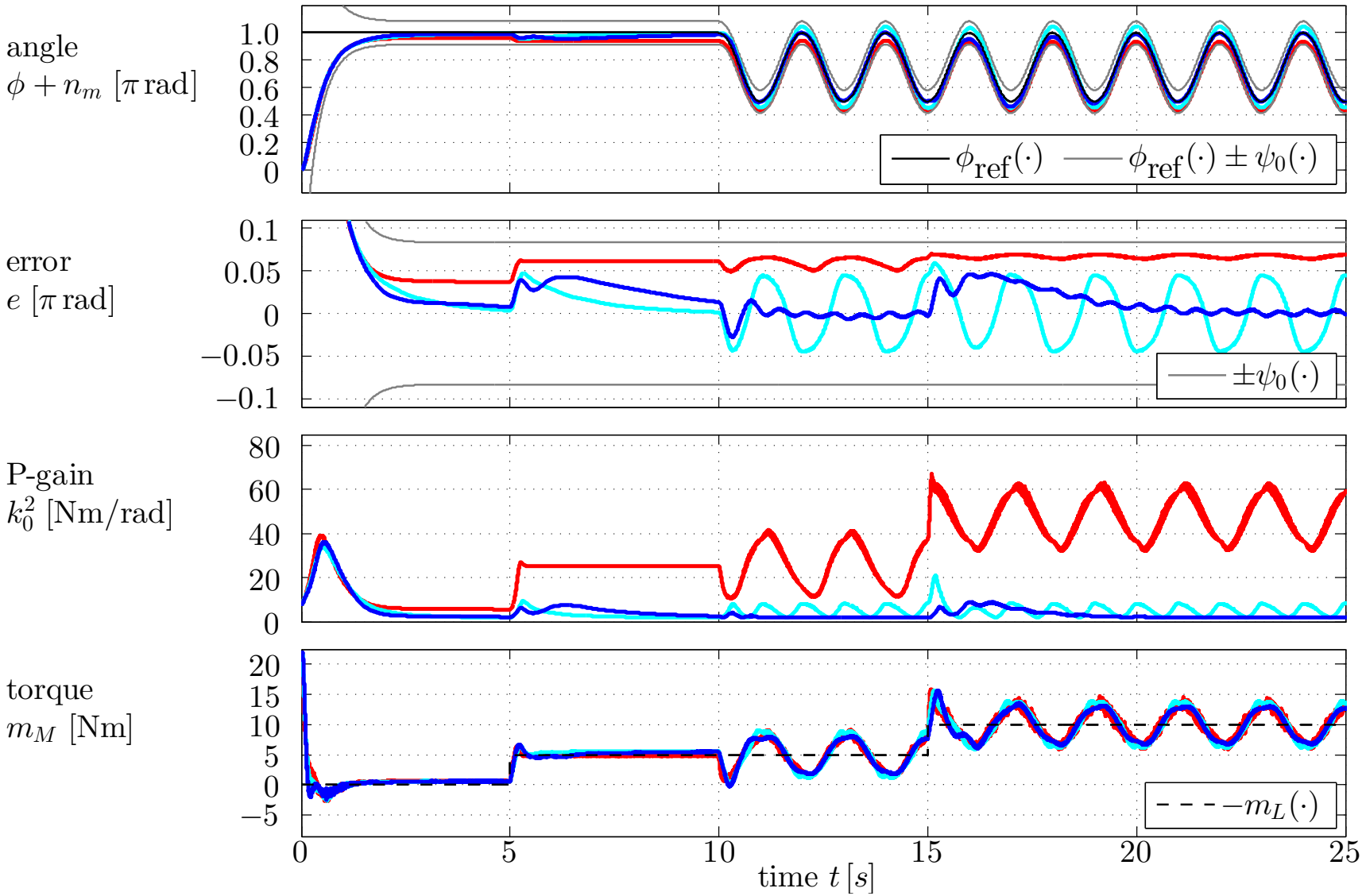
Positionsregelung von Industrieantrieben

Messergebnisse —(FC$_2$) (ohne Internes Modell) [5]



Positionsregelung von Industrieantrieben

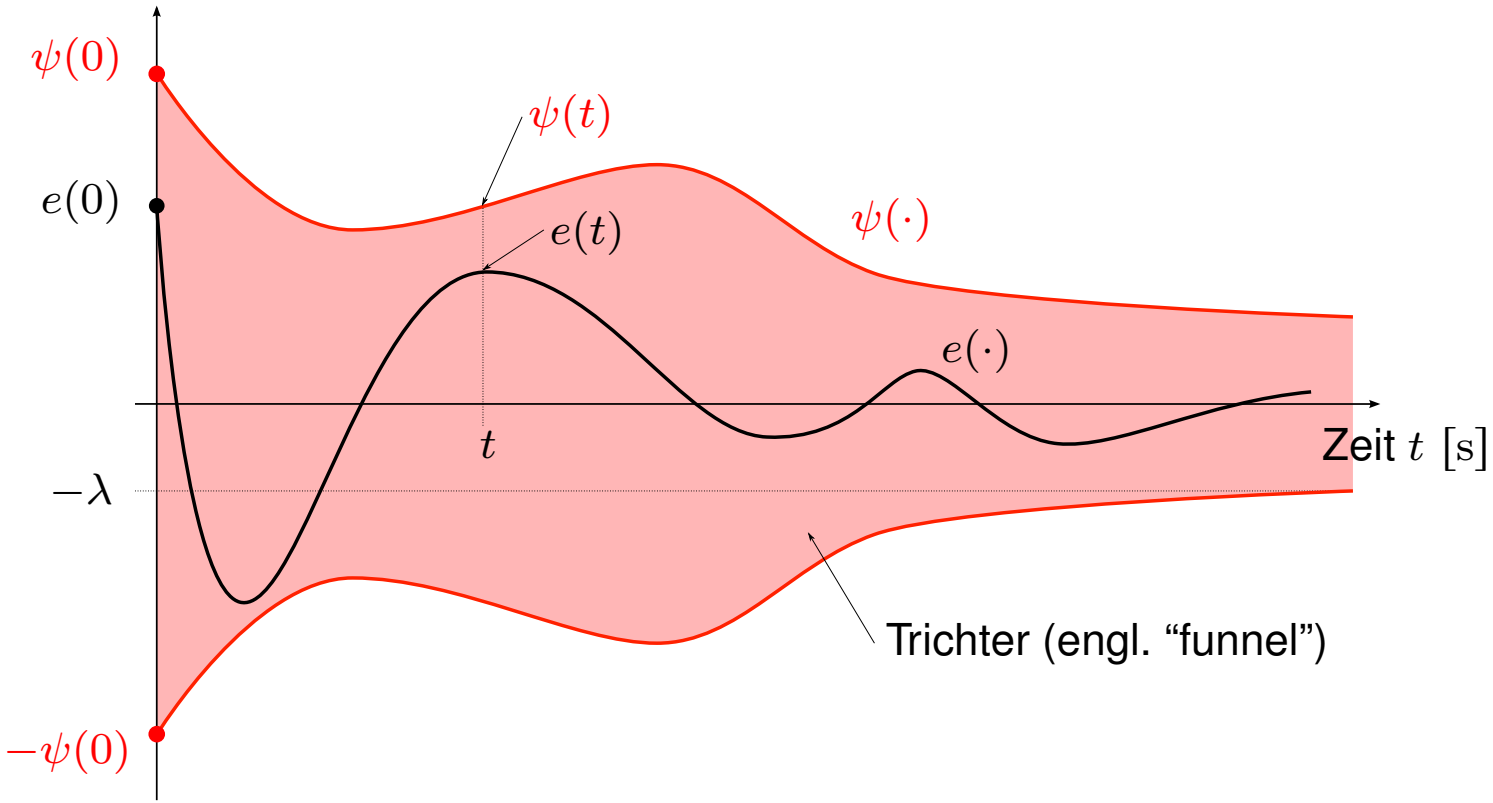
Messergebnisse —(FC$_2$), —(FC$_2$)+(PI), —(FC$_2$)+(IM) (mit internem Modell) [5]



Zusammenfassung

Funnel Control: Fakten

- **einfacher** und **robuster** Regler
- Vorgabe der **transienten Genauigkeit** (→ Trichterdesign)

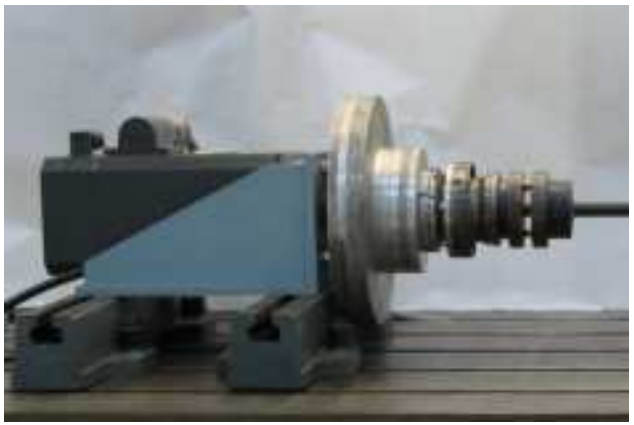


- **Asymptotische Genauigkeit** möglich (→ Interne Modelle, z.B. PI)

Zusammenfassung

Funnel Control: Erfolgreiche Implementierungen und Anwendungen [3, 5–36]

Industrieantriebe



Geschwindigkeits-/Positionsregelung

Industrieroboter

Positionsregelung

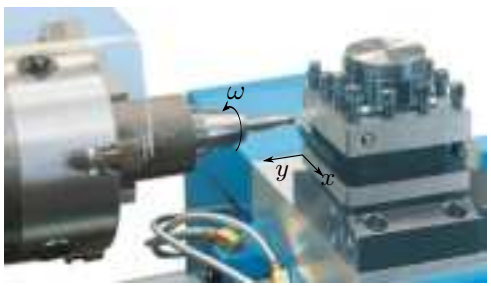
Windkraftanlagen

Geschwindigkeitsregelung

Elastische Antriebssysteme

Geschw.-/Positionsregelung + Dämpfung

Werkzeugmaschinen



Geschw.-/Positionsregelung

Elektrische Maschinen

Stromregelung

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