TUMCREATE

The (future) electrical power system dynamics: A systems theoretical point of view

Christoph Hackl

Head of Research Group “Control of Renewable Energy Systems (CRES)”, TUM

www.cres.mse.tum.de

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CREATE Tower, Singapore

Outline

1. Why will dynamics become more important?
2. What should we do about it?
3. What are we doing about it?

Why will dynamics become more important?

The future power system: A likely guess

- more distributed generation / **renewable energy systems**
- diminishing mechanical inertia
- hybrid grid and transmission topologies (e.g. AC & DC)
- more **unbalanced faults** ($> 75\%$ of faults already today)
- more loosely-coupled & unbalanced micro-grids
- more **power electronics**

$\Longrightarrow$ Faster dynamics/transients, more harmonics & weaker overall grid!

$\Longrightarrow$ Stationary models considering fundamental only *not* sufficient!

$\Longrightarrow$ Multi-phase multi-wire state-space models crucial!

Why will dynamics become more important?

The dynamics of the (future) power system

Coupled, time-varying partial differential algebraic system (PDAS):

$$\boldsymbol{f}\left(\tfrac{\partial}{\partial t}\boldsymbol{z}(t,x), \tfrac{\partial}{\partial x}\boldsymbol{z}(t,x), \boldsymbol{z}(t,x), \ldots, t\right) = \mathbf{0}_n$$

where $\quad \boldsymbol{z}(t,x) := \begin{pmatrix} \boldsymbol{\omega}(t) \\ \boldsymbol{\delta}(t) \\ \boldsymbol{v}(t,x) \\ \boldsymbol{i}(t,x) \end{pmatrix}$

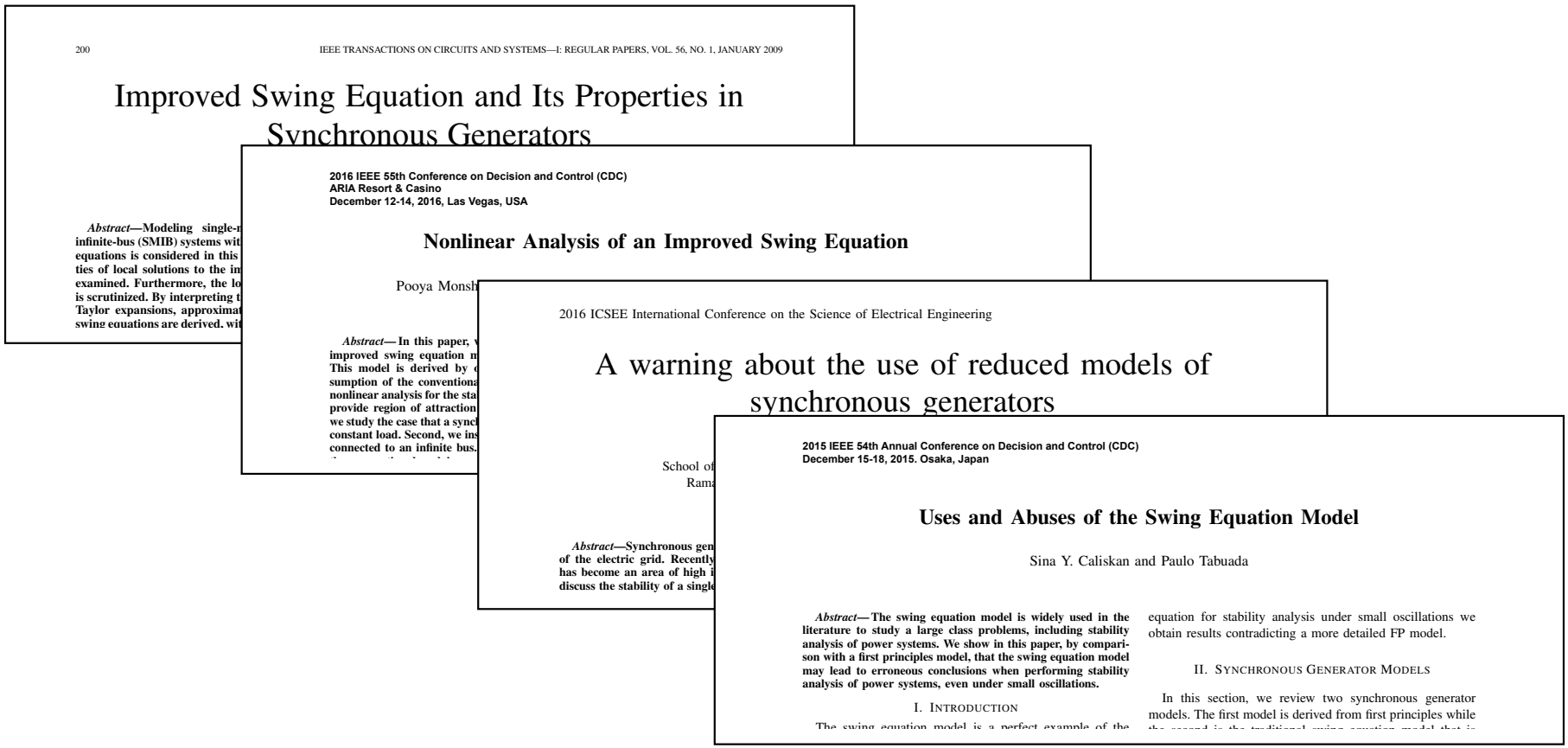
Several simplifying assumptions have to be **RE**-considered, e.g.

- $\frac{\partial}{\partial x}\boldsymbol{z}(t,x) = \mathbf{0}_m$, i.e. Π- or T-models (?)
- $\frac{\partial}{\partial t}\boldsymbol{z}(t,x) = j\omega\underline{\boldsymbol{Z}}(x)\mathrm{e}^{j\omega t}$, $\omega > 0$ (?)
- losses (?)
- time-variance (?)
- detailed low-level models (?)
- ...

Why will dynamics become more important?

Built on many assumptions: **The swing equation**

$$M\frac{\mathrm{d}^2}{\mathrm{d}t^2}\delta + D_\mathrm{d}\frac{\mathrm{d}}{\mathrm{d}t}\delta = p_\mathrm{t}(t) - \hat{p}_\mathrm{el}\sin(\delta)$$



200 IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS—I: REGULAR PAPERS, VOL. 56, NO. 1, JANUARY 2009

Improved Swing Equation and Its Properties in Synchronous Generators

2016 IEEE 55th Conference on Decision and Control (CDC)
ARIA Resort & Casino
December 12-14, 2016, Las Vegas, USA

Nonlinear Analysis of an Improved Swing Equation

Pooya Monsh

2016 ICSEE International Conference on the Science of Electrical Engineering

A warning about the use of reduced models of synchronous generators

School of
Rama

2015 IEEE 54th Annual Conference on Decision and Control (CDC)
December 15-18, 2015. Osaka, Japan

Uses and Abuses of the Swing Equation Model

Sina Y. Caliskan and Paulo Tabuada

Abstract— The swing equation model is widely used in the literature to study a large class problems, including stability analysis of power systems. We show in this paper, by comparison with a first principles model, that the swing equation model may lead to erroneous conclusions when performing stability analysis of power systems, even under small oscillations.

I. Introduction

equation for stability analysis under small oscillations we obtain results contradicting a more detailed FP model.

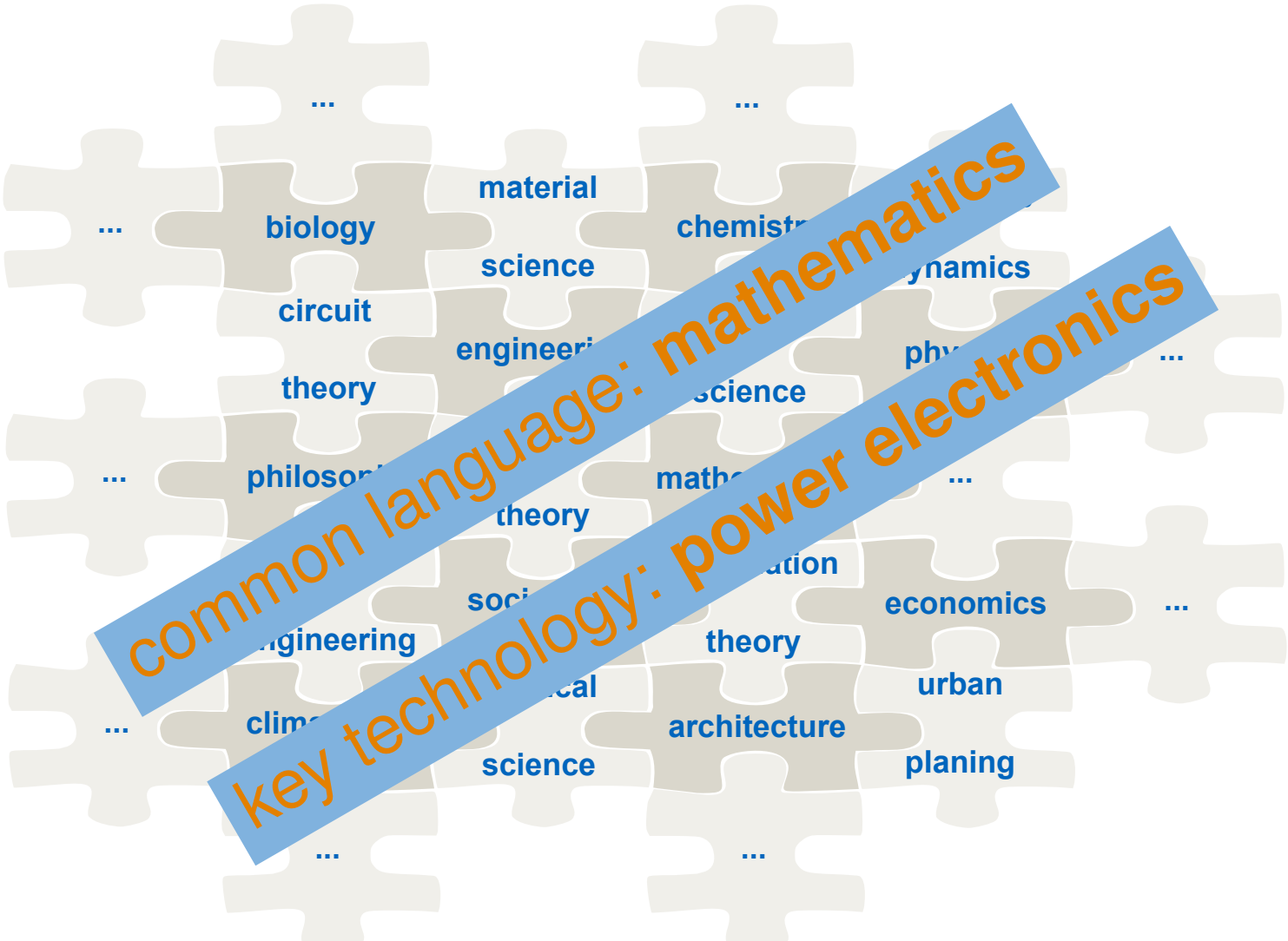
II. Synchronous Generator Models

In this section, we review two synchronous generator models. The first model is derived from first principles while

"...the results in this paper call into question the scientific foundations upon which the current power grid has been built." [1]

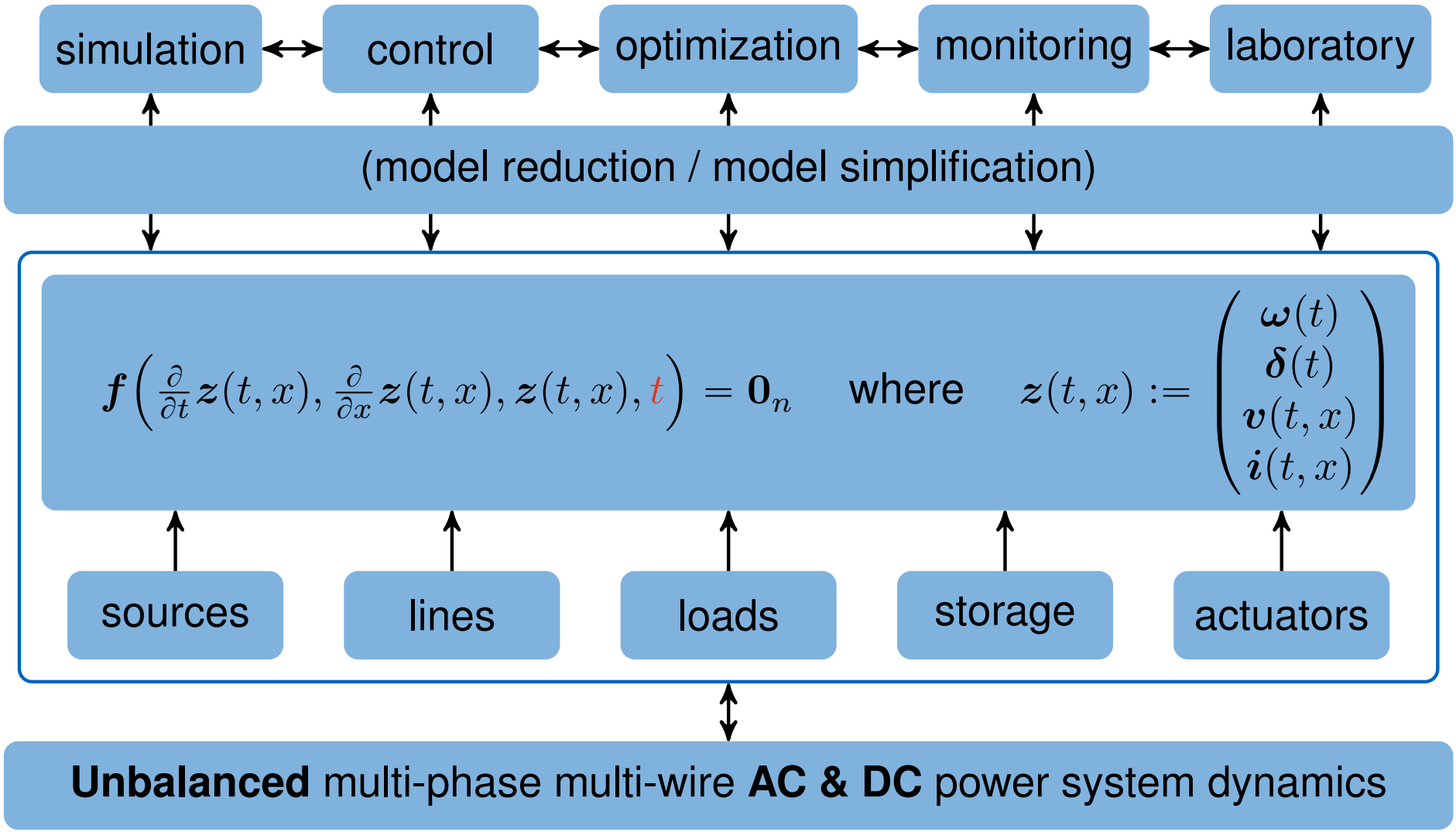
What should we do about it?

Interdisciplinary research: A lot of collaboration required!



What should we do about it?

Interdisciplinary research: Bottom-up approach (and, meanwhile, top-down approach)



What are we doing about it?

CRES: Running projects (third-party funding > 2 million €) and > 40 publications (since 2014)

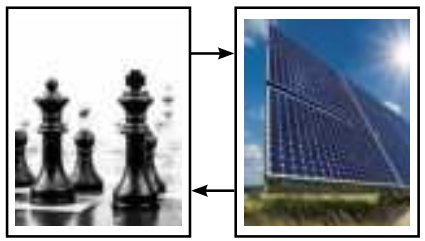
Large-scale WTS

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

Electrical power system

Three-phase four-wire system dynamics

What are we doing about it?

Activities at TUM-CREATE

- Lecture on each Thursday (May-July)

TUM CREATE Scientific Lecture:

Modeling and Control of Renewable Energy Systems

Dates (Thursdays, 13 sessions)

4 May	11 May	18 May
25 May	1 Jun	8 Jun
15 Jun	22 Jun	29 Jun
6 Jul	13 Jul	20 Jul
27 Jul		

Time
10:00 am to 12:15 pm

Venue
Theatrette, Level 2, CREATE Tower

- Seminar “Selected topics in energy research” on each Friday (May-July)
- Unbalanced modeling of four-wire three-phase systems (collaborative research)
- Refinement of the swing equation (collaborative research)
- ...

References I

[1] Sina Y. Caliskan and Paulo Tabuada. Uses and abuses of the swing equation model. In *2015 54th IEEE Conference on Decision and Control (CDC)*. IEEE, dec 2015.