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# Open Source Modeling for Power Systems Dynamics

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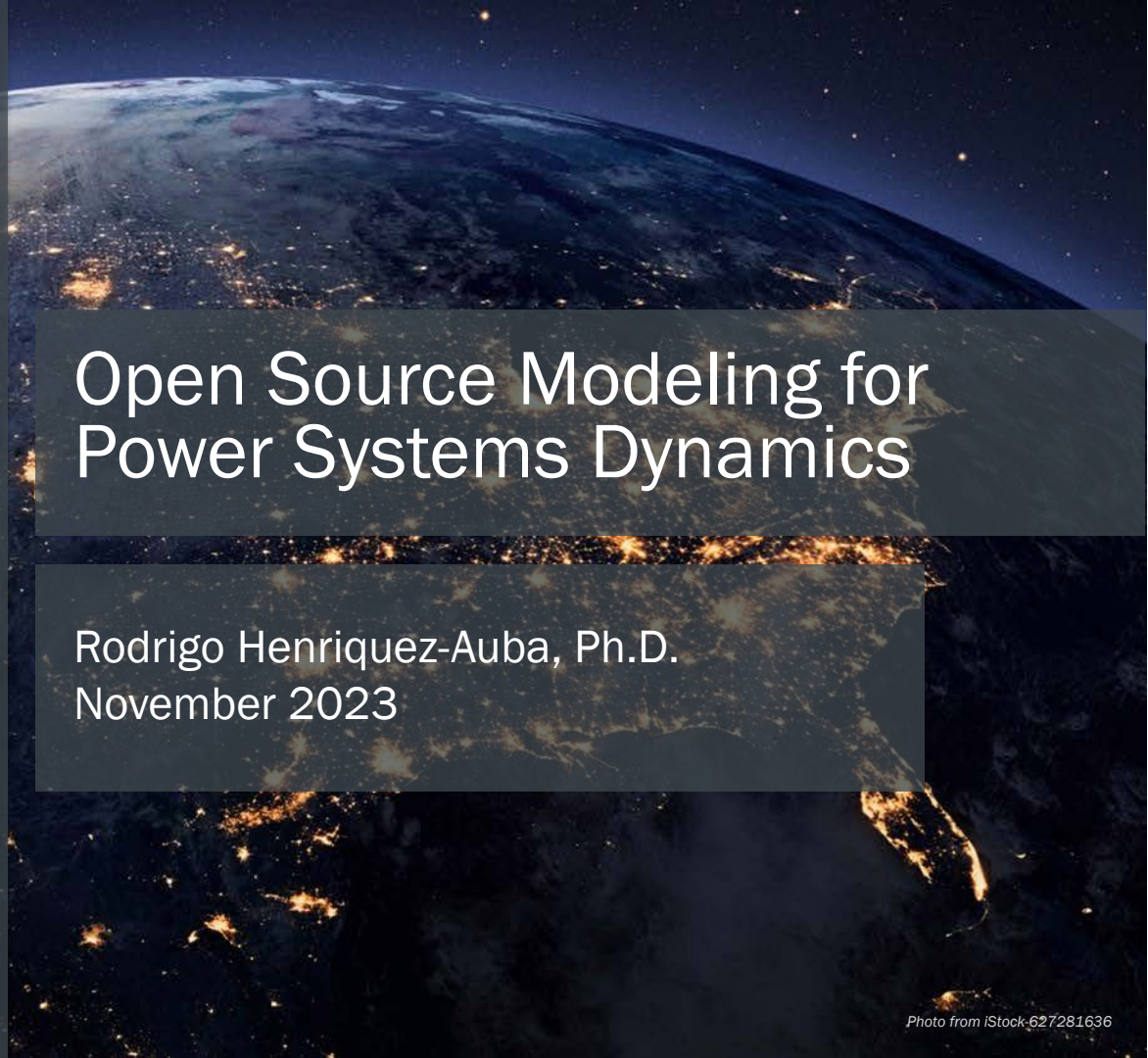
November 2023



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# Open-source in power systems dynamics

The experience with PSAT has taught me that the power system community **is simply not responding properly to open-source projects**. In the last ten years, third-party contributions to PSAT have been very marginal or would have been developed even if PSAT had been not distributed as a free and open-source project…

**I got to the conclusion that the free and open-source paradigm is not attractive for small and closed communities like the power system one**.

**Prof. Federico Milano,** http://faraday1.ucd.ie/dome

# Is it true?

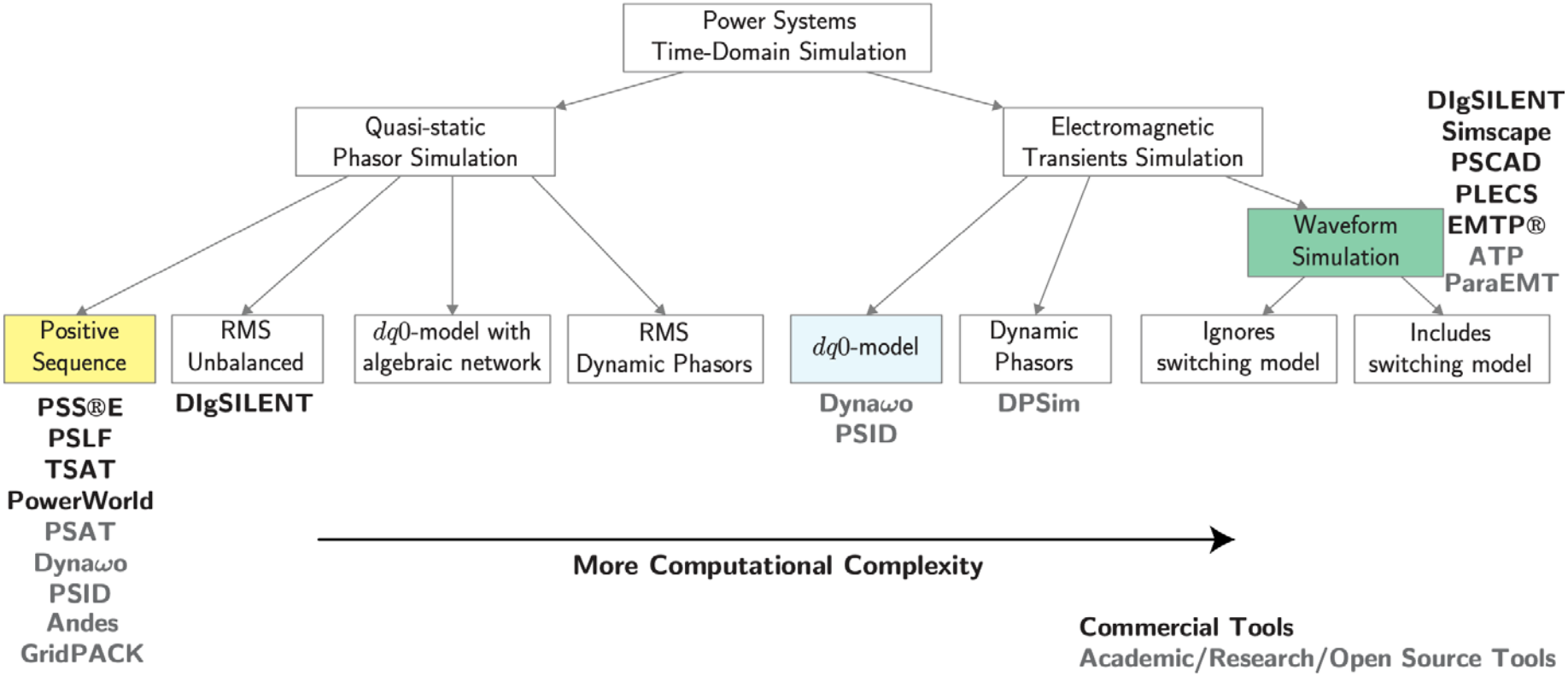
## Kind off…

Although, I'm not sure the reasons are that the community is closed or not willing to collaborate… I mean, is enough to look at this workshop.

- Main reason is that power systems, particularly in time-domain dynamic simulations, is **not taught from a software perspective**.
- The focus is given in understanding power system phenomena, such as voltage collapse, rotor stability, sub-synchronous oscillations, etc., **by using existing tools.**
- As a result, people interested in the area most likely will not have the **software skills** to contribute to open-source tools.

# Modeling Power System Dynamics

# There is a lot to model…



# A Generic Simulation Model

$$\frac{d\boldsymbol{x}(t)}{dt} = F(\boldsymbol{x}(t), \boldsymbol{y}(t), \boldsymbol{\eta}, t), \quad \boldsymbol{x}(t_0) = \boldsymbol{x}^0$$
$$\frac{d\boldsymbol{y}(t)}{dt} = G(\boldsymbol{x}(t), \boldsymbol{y}(t), \boldsymbol{\psi}, t), \quad \boldsymbol{y}(t_0) = \boldsymbol{y}^0$$

- $\boldsymbol{x}(t)$ and $\boldsymbol{y}(t)$ are generally complex valued vectors of variables. Certain formulations/implementations use real values.
- $\boldsymbol{x}(t)$ represents the variables for devices connected to grid.
- $\boldsymbol{y}(t)$ are the network variables, usually voltages and currents. In some formulations active/reactive power can be used but it is less common.

There are plenty of representations for $F(\cdot)$ and $G(\cdot)$, and the complexity of these functions what usually determined which simulation type is being considered.

# Different ways of integrating

**Implicit Scheme**

$$S_F(\boldsymbol{x}(t), \boldsymbol{y}(t), \boldsymbol{x}(t+\Delta t), \boldsymbol{y}(t+\Delta t), \boldsymbol{\eta}) = 0$$
$$S_G(\boldsymbol{x}(t), \boldsymbol{y}(t), \boldsymbol{x}(t+\Delta t), \boldsymbol{y}(t+\Delta t), \boldsymbol{\psi}) = 0$$

**Explicit Scheme**

$$\boldsymbol{x}(t+\Delta t) = E_F(\boldsymbol{x}(t), \boldsymbol{y}(t), \boldsymbol{\eta}, \Delta t)$$
$$\boldsymbol{y}(t+\Delta t) = E_G(\boldsymbol{x}(t), \boldsymbol{y}(t), \boldsymbol{\psi}, \Delta t)$$

In addition, in Differential-Algebraic Equations (DAEs):

- **Partitioned approach:** Solve separately the differential equations with the algebraic ones.
- **Simultaneous approach:** Solve together both differential and algebraic equations.

Most phasor industry tools, such as PSS/E or PSLF, uses the partitioned approach and also have heuristics to accelerate and improve convergence.

# Huge advantage from commercial tools

- Siemens PTI PSS/E was introduced in 1976
- PowerFactory DIgSILENT first released in 1985
- PowerWorld was released in 1996
- Development of EMTP simulators started in 1966
- PSCAD was released in 1988

Number of features and capabilities clearly exceeds any open-source tool. For example, PSS/E has over 500 device models including generators, exciters, governors, loads, FACTS, relays, etc.

**We are lucky to get a GUI in our open-source tools.**

# Are we not prepared for the challenges then?

## Not really…

Integration of renewables is changing the fundamental dynamical principles of how electricity is produced, and how our grid operates.
Fast inverters are affecting the numerical accuracy of our well-known positive sequence tools and giving opportunities to explore new methods.

# New open-source tools

ANDES

CURENT

https://github.com/CURENT/andes

Sienna\Dyn

Simulation of power system dynamic response to disturbances and contingencies

https://github.com/NREL-Sienna/PowerSimulationsDynamics.jl

LF ENERGY

Dynawo

https://github.com/dynawo/dynawo

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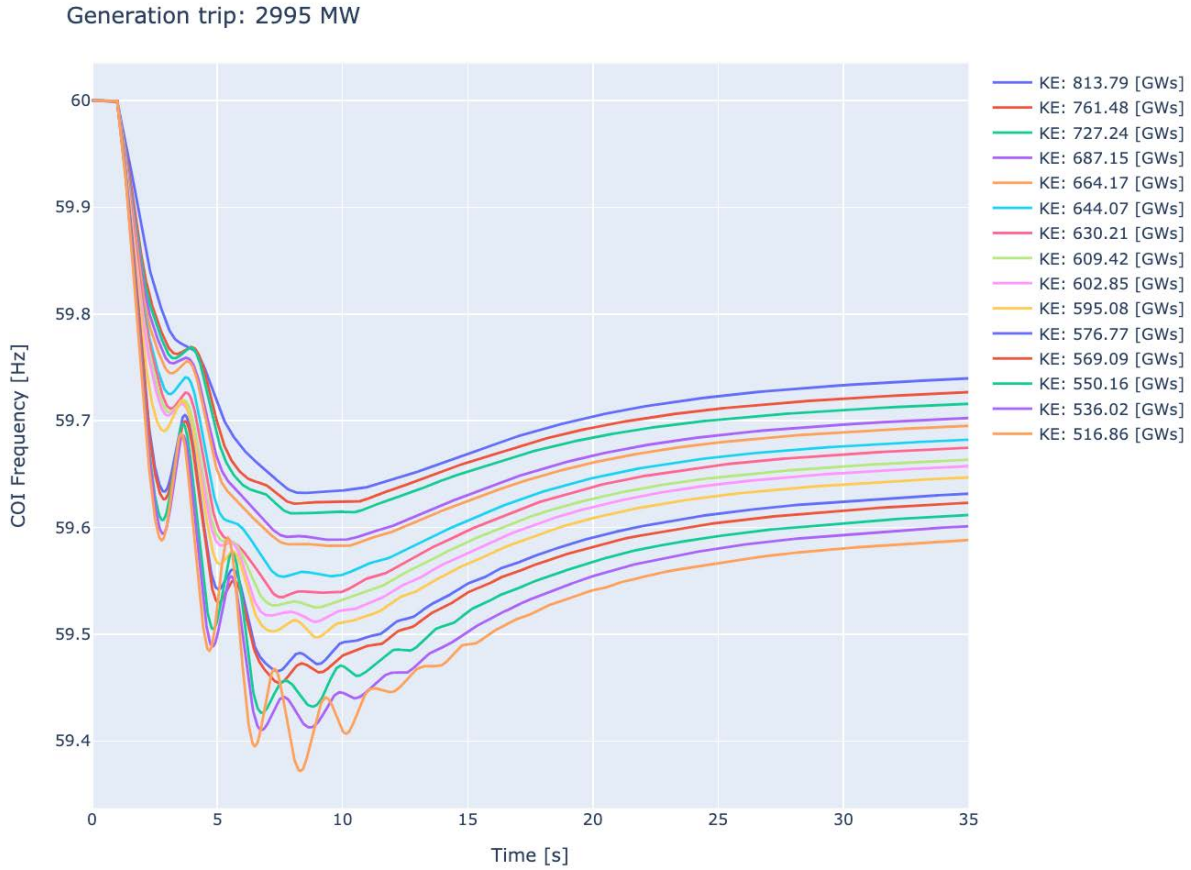
GridPACK™

https://github.com/GridOPTICS/GridPACK

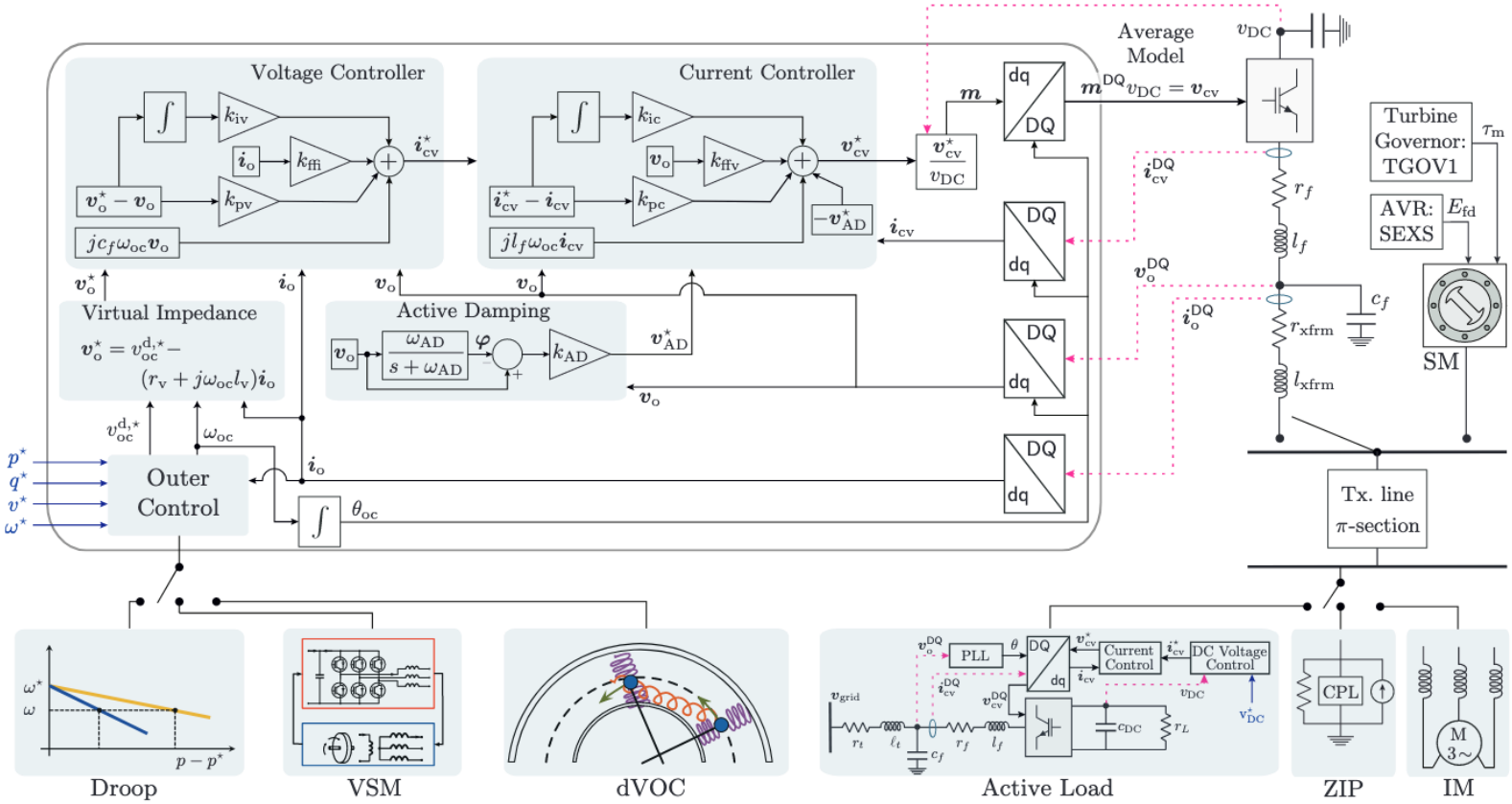
# Existing cases of Open-Source Tools in Power Systems Dynamics

# Example: Critical Inertia Assesment

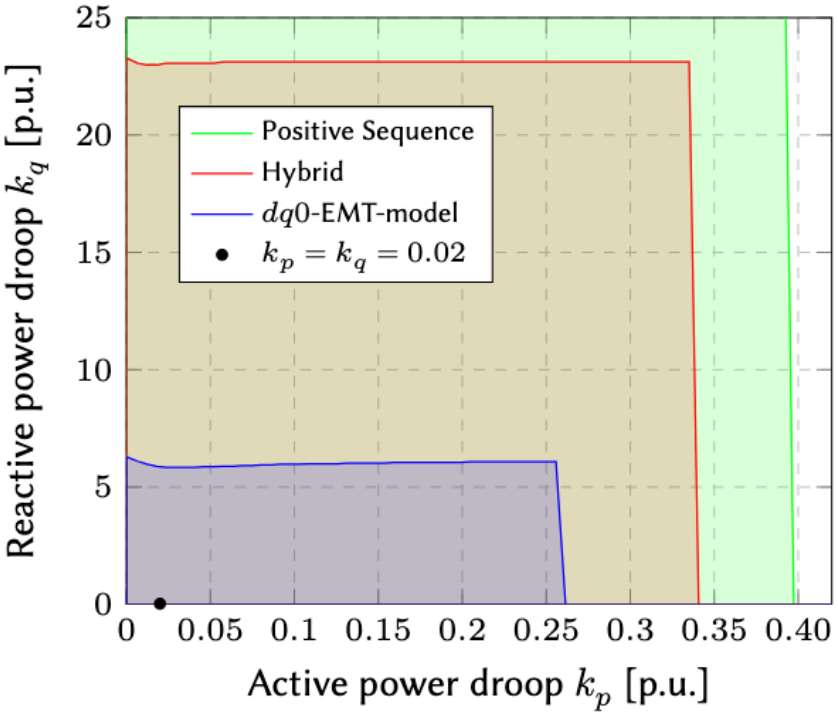



- Exploring reduction of inertia by replacing SM by IBRs
- Enable frequency control in IBRs.
- Disable governors for frequency studies.

# Example: Test different IBR controllers



# Example: Small-Signal Stability with line dynamics




Small signal stability regions for active/reactive droop on GFM.

- Regions of stability can be explored with different model assumptions
- In this case, enabling differential equations for network (transmission line currents and bus voltages) or not.

# Example: Co-Simulation GridPACK and ParaEMT

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GridPACK™

ParaEMT

Hierarchical Engine for Large-Scale Infrastructure Co-Simulation (HELICS)

# What's next?

- The key question to answer for us:
  - **What should the key focus for the open-source community?**
- There are some gaps already observed:
  - Extend capabilities of existing phasor tools
  - Use existing methodological techniques to expand waveform tools
  - Focus in new dq0 tools that are high quality. Take the opportunity of missing a proper commercial tool here.
  - Focus on new models: detailed transmission lines, accurate IBR models, handling variability, limiting behavior.

# Thank you

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This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by the AGM program R2D2 project from the Office of Electricity. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

NREL/PR-6A40-88085

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