Energy Storage Control to Improve Transient Stability in Low-Inertia Power Grids

PRESENTED BY

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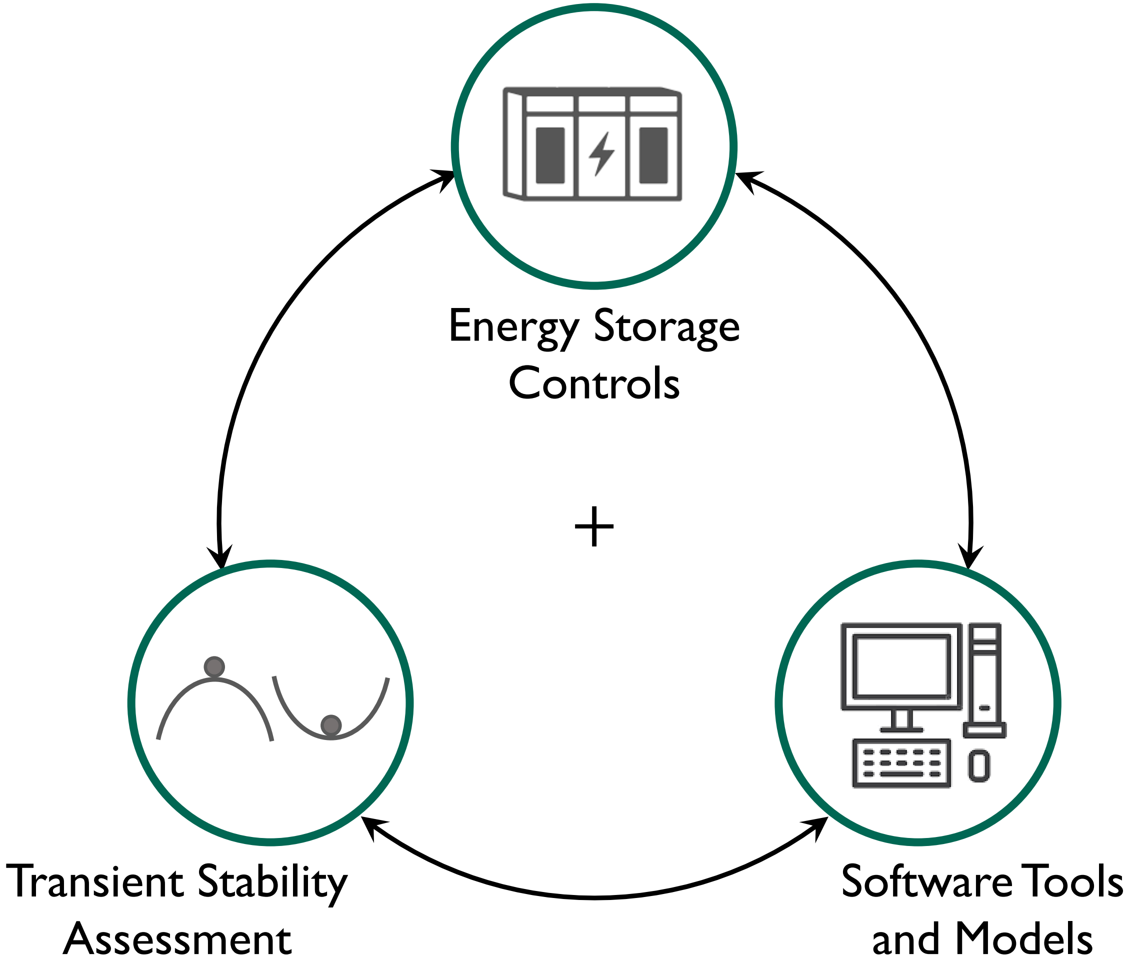
Project overview

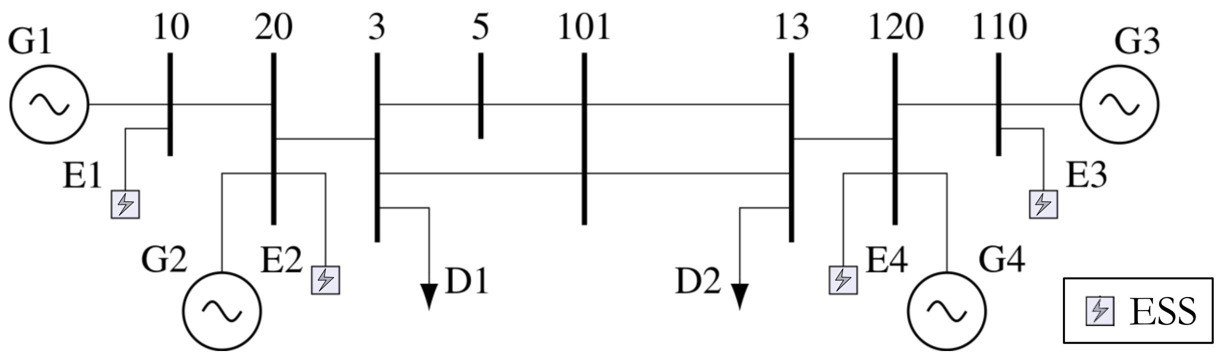
- The way transient stability is maintained must adapt to a changing resource mix.
- Energy storage controls can improve transient stability and reduce curtailment.
- Data-driven stability assessment methods are needed for high renewable penetration.
- Open-source software tools and models can accelerate deployment of ESSs.
- Preparing an invited paper for IEEE Access on these topics.



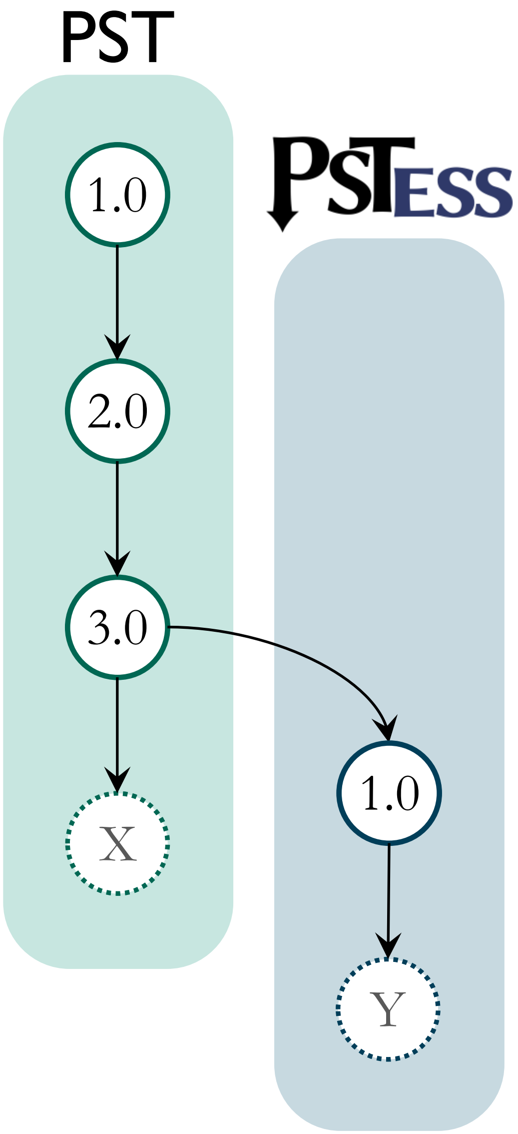
Software tools and models: Introducing PSTess

- This fiscal year, we released an open-source software package called the *Power and Energy Storage Systems Toolbox*, or PSTess for short.
- It enables advanced dynamic analysis of large-scale power systems with utility-scale, inverter-based energy storage systems (ESSs).
- For more information, see: https://github.com/sandialabs/snl-pstess

  R. Elliott, D. Trudnowski, H. Choi, T. Nguyen, "The Power and Energy Storage Systems Toolbox – PSTess Version 1.0," September 2021, SAND2021-11259.
- To showcase the capabilities of PSTess, we developed versions of the Kundur 2-area system and the miniWECC augmented with energy storage.



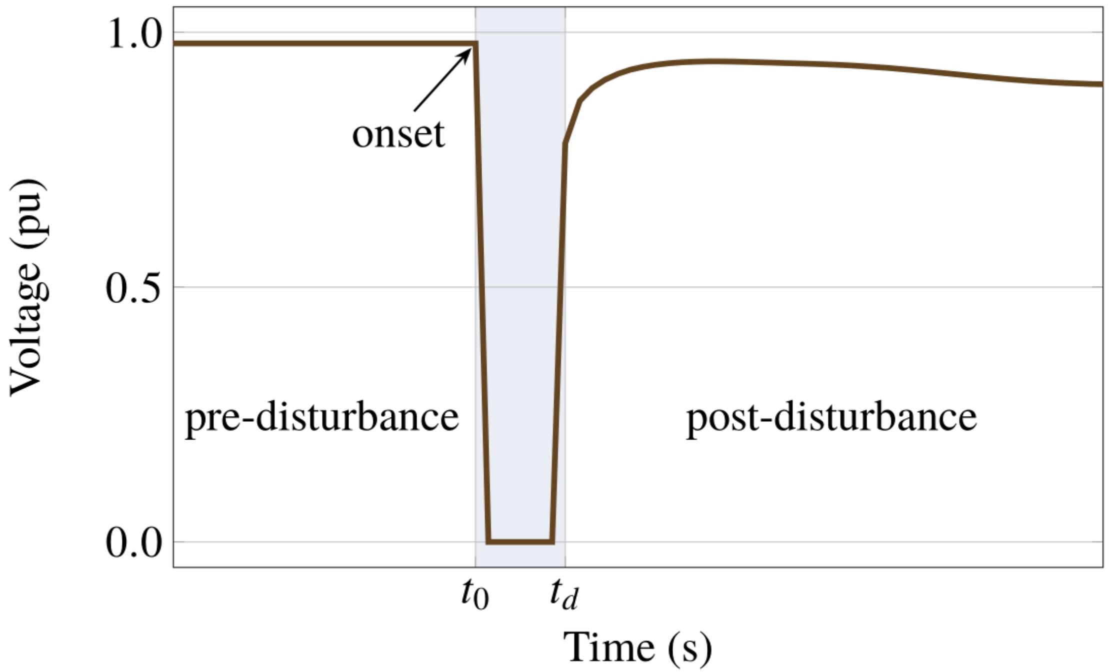
Kundur 2-area system with ESSs.



PST software version history.

Energy storage controls: Classification of objectives

- The primary objective of transient stability control is to maintain synchronism following a severe disturbance. Control strategies achieve this by:
  - Modifying the state trajectory during a disturbance to stay within the region of attraction;
  - Enlarging the region of attraction along key dimensions for critical contingencies; and/or,
  - Ensuring the existence of a stable post-disturbance equilibrium (in some circumstances).



Disturbance stages as a function of time.

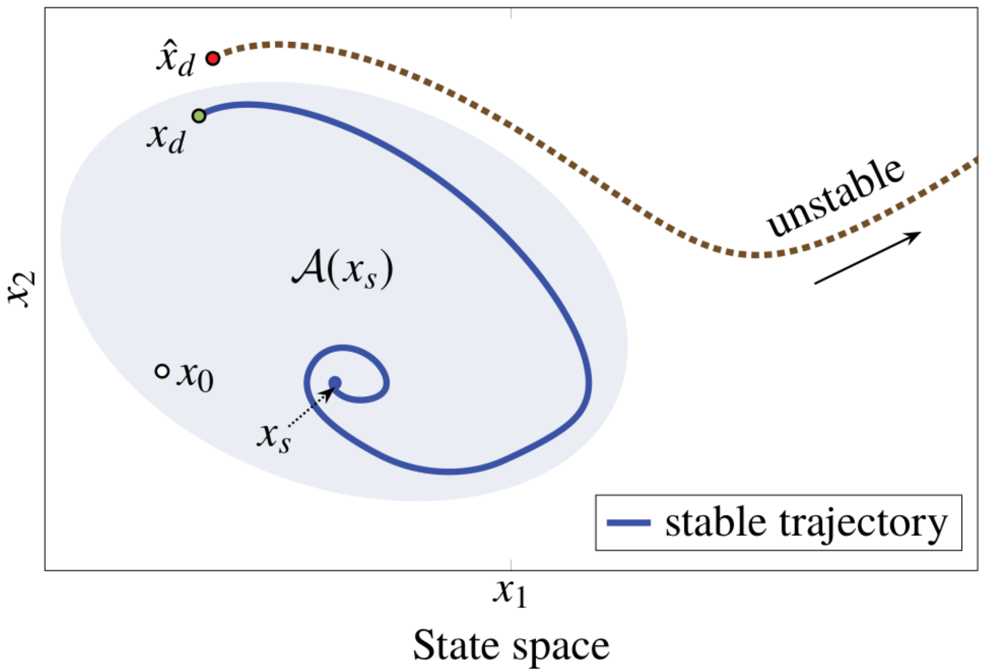
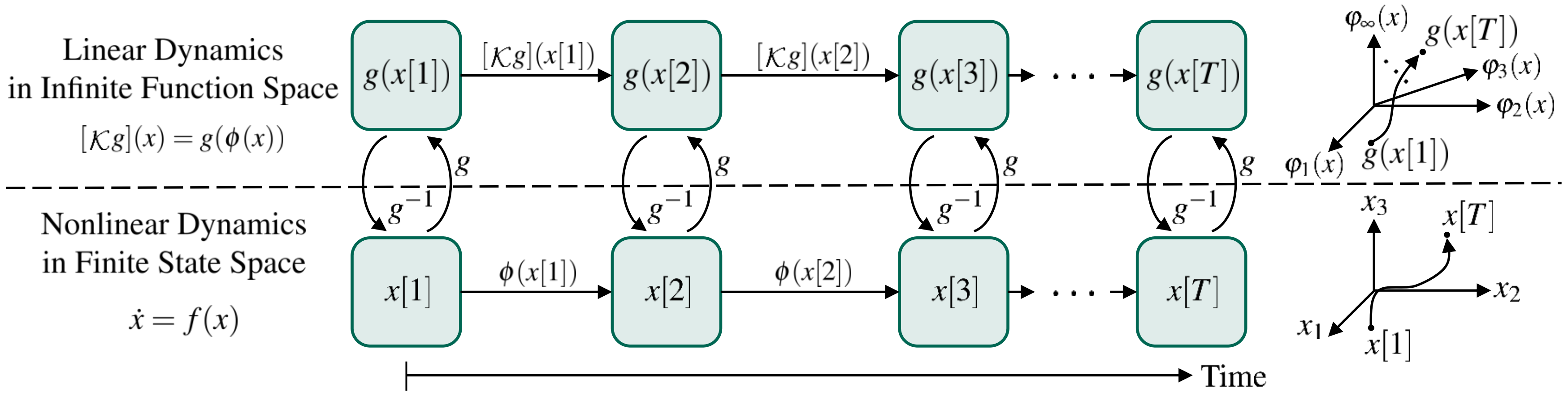


Illustration of the region of attraction (ROA).

Data-driven stability assessment: Koopman operator approach

- The Koopman operator provides equivalent linear representation of original nonlinear system in a function space.
- Spectral decomposition of the Koopman operator enables estimation of the ROA.

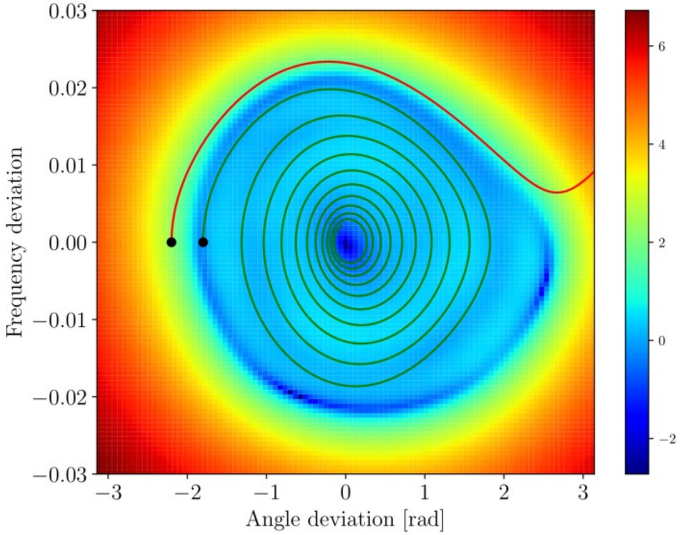


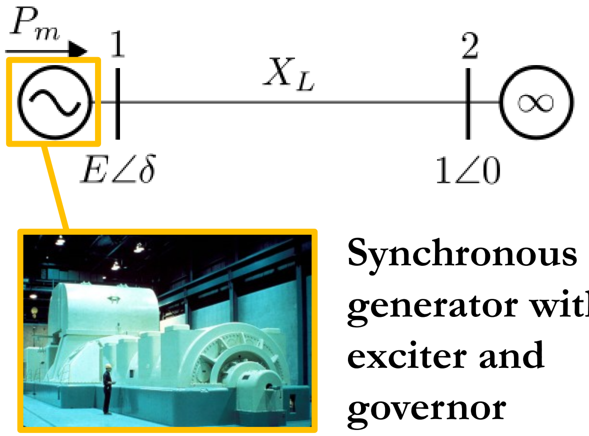
Spectral decomposition

$$g(x) = \sum_{k=1}^{\infty} v_i \lambda_i \varphi_i(x)$$

$\varphi_1(x)$

Dominant eigenfunction





Synchronous generator with exciter and governor