Stabilizing Transient Disturbances Using Utility-Scale Energy Storage Systems

Background

When power systems that lack sufficient synchronizing torque are subjected to a severe disturbance they may experience widespread power outages. To mitigate this risk, stability limits are imposed on certain transmission corridors that inhibit the full utilization of existing line capacity. In turn, this increases the investment and operation costs of the transmission system. The combination of utility-scale energy storage and wide-area measurement systems (WAMS) enables new approaches to address these problems [1]. This is a new start project that began in June of 2020.

Dynamic Models

For control applications, simulation models must account for energy storage and power electronic converter dynamics.

- We created dynamic models for the Matlab-based Power System Toolbox (PST).
- Fig. 1 shows an ESS model that tracks SOC, and Fig. 2 the converter interface.
- The models are linked, and the bounds on the converter output are dependent on the ESS state of charge.
- We will explore using a data-driven linear-predictor battery model to reduce computational burden for parameter estimation.

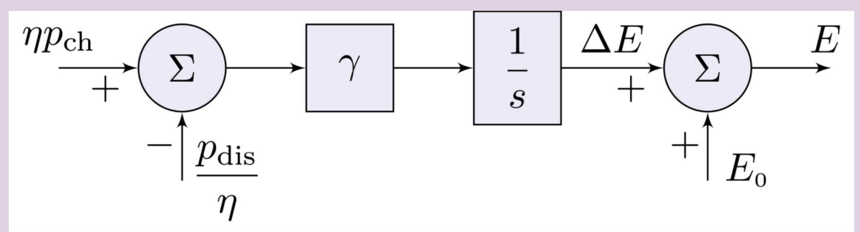

Fig. 1: Energy storage model that tracks the state of charge and accounts for nonideal efficiency.

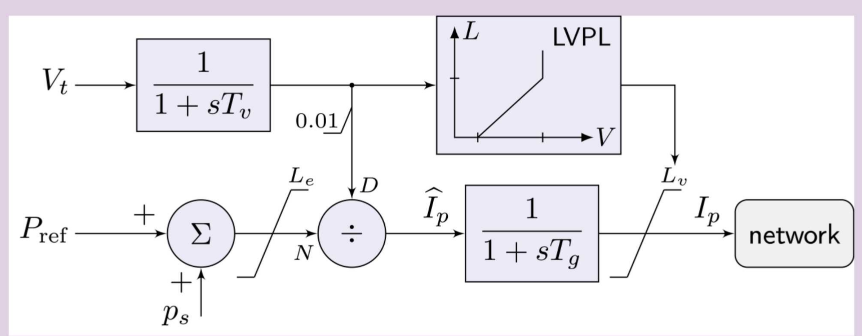

Fig. 2: Converter interface model that features a low-voltage power logic (LVPL) mechanism.

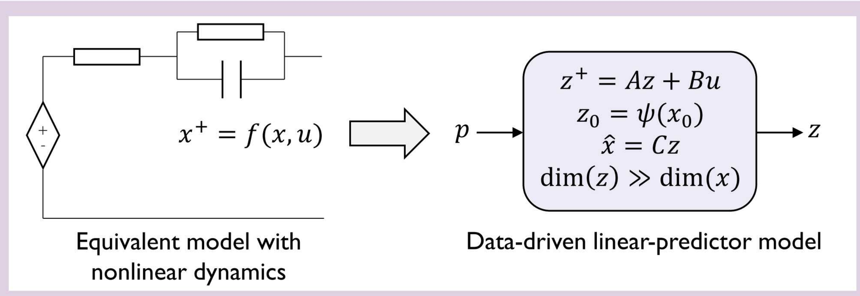

Fig. 3: Data-driven linear-predictor battery model which simplifies equivalent model construction.

Controls

This project will develop and compare multiple energy storage control strategies for improving transient stability:

- Development of feedback laws for stabilizing transient disturbances (e.g., angle vs. acceleration).
- Intra- vs. inter-area control. How to balance synchronizing individual machines with synchronizing sets of machines to prevent unintentional islanding.
- Centralized vs. decentralized control paradigms. What are the pros/cons of having the command signals computed at the control center vs. a local controller?
- Utilization of WAMS for identification of grid dynamics and control synthesis in a reduced-order model.

Stability Margins

The team will investigate techniques for quantifying the impact of energy storage control on transient stability margins. Methods of interest include:

- Estimation of the region of attraction using Koopman operator theory [2].
- Extensions of the equal-area criterion for multi-machine systems [3].
- Hybrid assessment techniques that combine analysis and simulation.

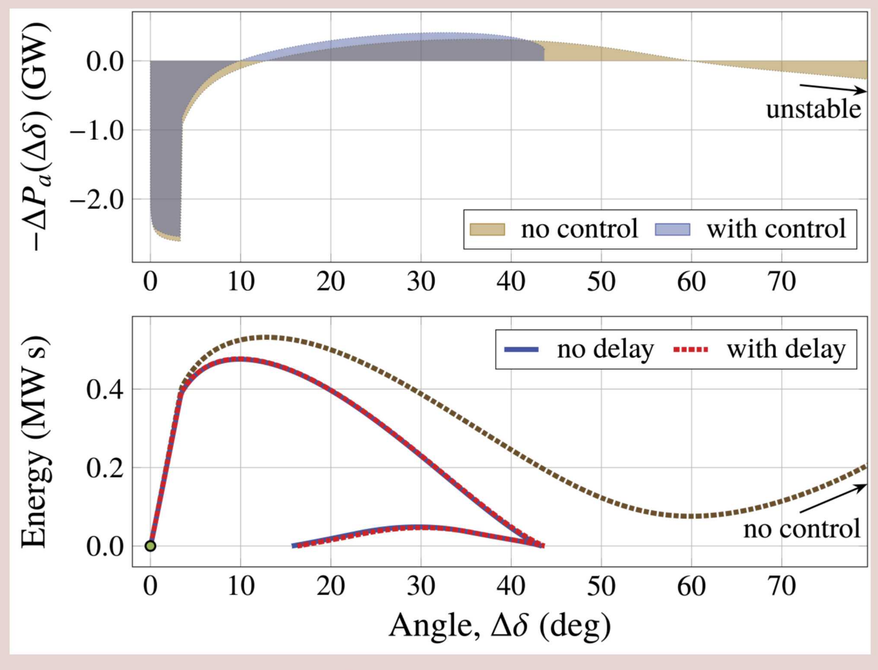

Fig. 4: An extension of the equal-area criterion in the center-of-inertia reference frame.

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