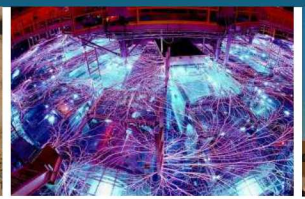
SAND2020-8351PE

Transient Stability Analysis using Nonlinear Control Methods



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Context

Goals of talk:

- Present an idea on transient stability control development that leverages nonlinear-based methods.
- Idea is separately being proposed to DOE-OE Advanced Grid Modeling (AGM) program, managed by Dr. Ali Ghassemian, and no decision on whether or not to fund this idea has been made at this time.
- If funded, the proposed idea has good potential for synergies with the interests and goals of TSAWG.
- We (SNL and MTU) do have a scope of work proposed, but there is flexibility in this to perform work that may help WECC/TSAWG in their mission.
- Therefore, feedback during and after the talk on work to consider is highly encouraged!

Motivation

- Transient stability is highly correlated to the inertia connected to the synchronous grid.
- Nearly all modern control schemes for maintaining transient stability involve synchronous generator tripping schemes.
- As the penetration of inverter-based and distributed generation increases, tripping schemes will become more difficult to apply due to the wide distribution of the generation and the loss of system inertia.
- The potential for transient stability margins to worsen in the future grid is a primary motivation for the study of new, especially nonlinear, techniques.

Introduction

- Idea will investigate nonlinear control strategies for transient stability in wide-area power systems
- Nonlinear control methods have historically not been viewed as practical in large grids
- Recent advances in and proliferation of high-speed wide-area measurements ➔ enables the use of previously unavailable signals for feedback control
- Rapid proliferation of inverter-based resources ➔ enables implementation of distributed and decentralized control strategies
- Joint idea between Sandia and Montana Tech – teamed together on highly successful BPA damping control project

Problem Statement

- Definition of transient stability:

  Ability of a power system to maintain synchronism when subjected to significant disturbances, e.g., major line trips, large gen trips, loss of large loads

  ➔ large excursions of rotor angles

  ➔ swing equation is nonlinear

- Currently, the most common approaches to analysis of transient stability:

  (1) analysis and design based on linearized model(s)

  (2) high fidelity simulation studies (e.g., WECC base cases in PSLF, PSSE, PowerWorld)

  (3) iteration between (1) and (2)

Proposed Work (subject to change)

Tasks proposed over two years, FY21 and FY22:
(not necessarily performed in the order listed here and some tasks will be concurrent with others)

- Thorough literature survey of transient stability concepts and control methods based on nonlinear dynamics theory
- Leveraging nonlinear methods, develop control strategies to improve wide-area transient stability
- Coordinate transient stability control strategies with small signal stability control (e.g., damping control)
- Incorporate wide-area measurements (if available) and leverage estimation techniques to obtain appropriate feedback signals
- Demonstrate performance of developed transient stability control methods on real-world grid models: MiniWECC, WECC base cases, etc.
- Investigate performance of developed methods for grids (e.g., WECC) with very high penetration of inverter-based generation

Background

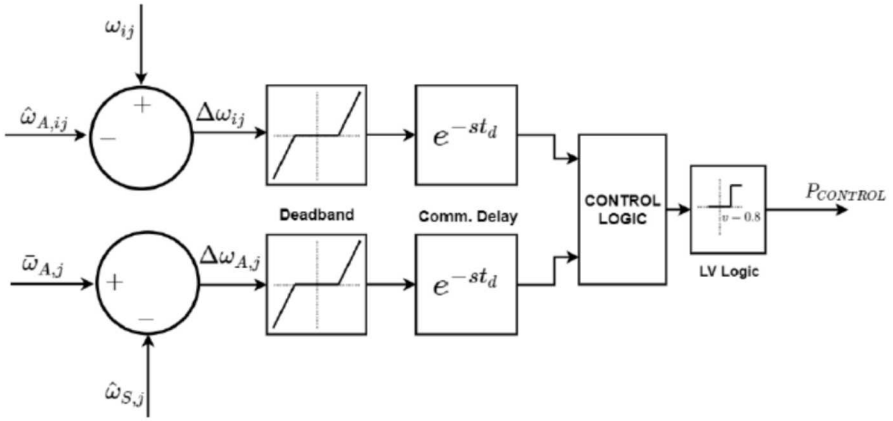
Nonlinear control approaches studied in last 20-25 years:

- Equal area criterion
- Lyapunov-based stability analysis
- Partial energy functions
- Hamiltonian-based nonlinear power flow techniques
- Control design based on metrics of stability margins, e.g., generalized gain margin, gap metric
- More recently, machine learning is being leveraged to incorporate more complex component models

Recent Work

Prior recent work in this area conducted by MTU/SNL:

- Work based on equal area criterion and energy functions – Dr. Sam Ojetola (MTU Ph.D. graduate and very soon (Sept 2020) to start career at Sandia)
- Uses power modulation of energy storage devices for actuation (other sources of real power injection can also be leveraged, e.g., thyristor braking, HVDC)
- System is broken into areas based on groupings of generators
- Control strategy uses two parallel feedback loops
- First loop focuses on preserving synchronism of a given generator in its own area
- Second loop focuses on preserving synchronism of a given area with other areas
- Local frequency and center of inertia frequency measurements are used for feedback signals



Thank You!

Questions?

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