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SAND2018-11067C

Estimation of Generator Control System Performance using Synchrophasor Data

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- Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.
- This research was supported in part by the U.S. Department of Energy Transmission Reliability program.
- This work was supported in part by the Engineering Research Center Program of the National Science Foundation and the Department of Energy under NSF Award Number EEC-1041877 and the CURENT Industry Partnership Program.

Overview

- Voltage and frequency response from control systems (e.g., SVC/STATCOM, excitation systems, governing, wind turbines control systems, etc.)
- Not interested in identifying generator parameters and other fast components outside of the PMU sampling bandwidth
- Objective is to use disturbance and ambient PMU to monitor control performance
- The goal is to automate the monitoring process to track changes in the recorded performance, such that equipment operation issues can be identified before equipment starting to fail.

Generator Performance

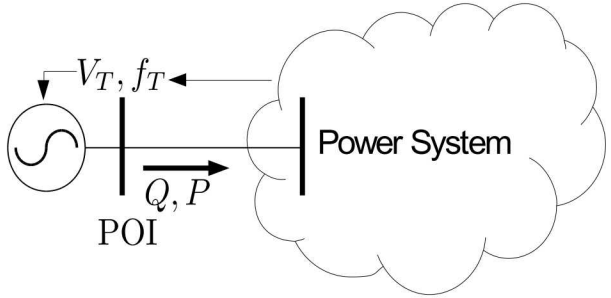
- Current approach:
  - Use PMU data for generator model parameter identification
  - Challenges:
    - Small time constants associated with machine subtransient circuits are not readily identifiable
    - WTG Units have multiple control modes and it may not be clear which mode is in operation
    - Parameter identification tends to be a manual tuning process

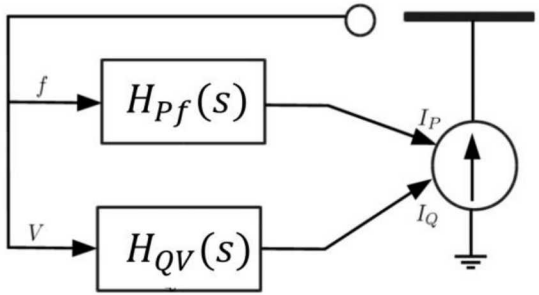
Generator Performance Goals

- Focus on frequency and voltage regulation of power system control equipment
  - Frequency regulation: active power control provided by governors and energy storage systems
  - Voltage regulation: reactive power control provided by excitation systems, static var systems, STATCOM, power-electronic interface with renewables
- Performance monitoring using PMU data
  - Disturbance events and ambient conditions
  - Identify simple transfer functions:
    - a droop
    - a time constant
    - Simpler than full model parameter identification

Full model vs simplified dynamic model

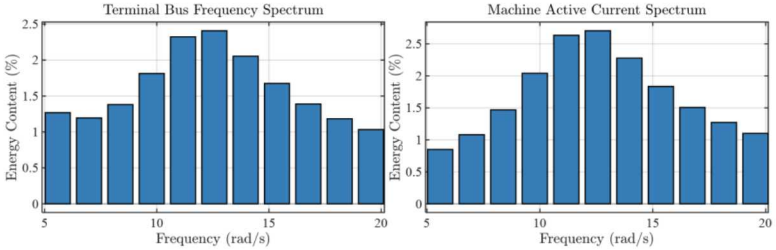
- Full Model:
  - 9th order subtransient model
  - Used to obtain point of interconnection (POI) measurements
- Simplified dynamic model
  - Decoupled active and reactive
  - First order model
  - Obtained by
    - Model reduction based approach
    - Signal analysis based approach

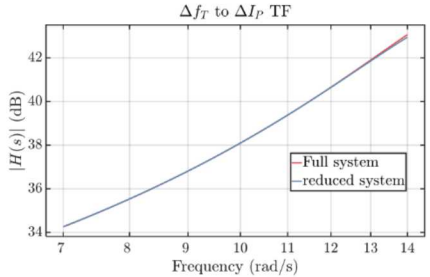


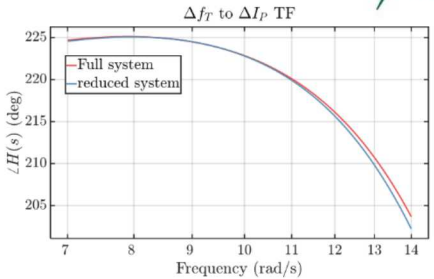


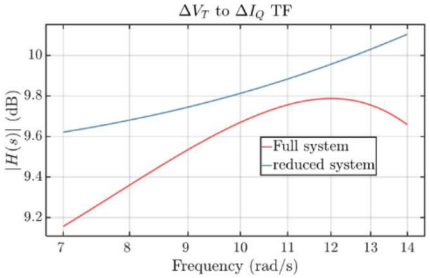
Model Reduction Based Aproach

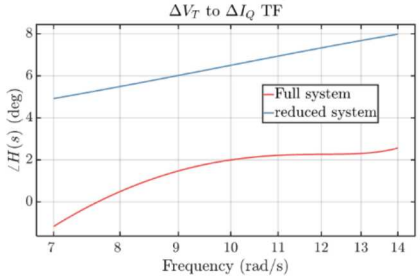
- Use POI measurements to determine frequency of interest
- Balanced model reduction to approximate first order model





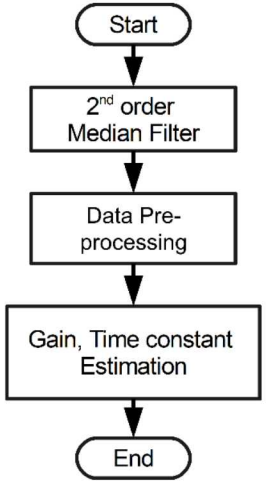


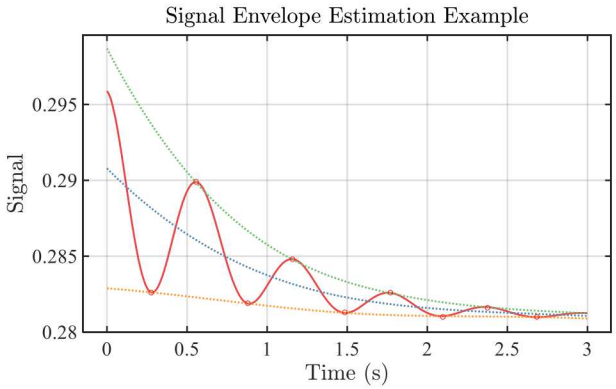




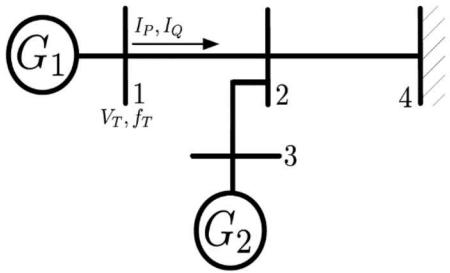
Signal Analysis Based Aproach

- Signal Pre-processing
  - Filter to remove noise
  - Remove missing data
  - Estimate center envelope to remove DC bias
- Estimate a first order transfer function using numerical optimization of the prediction error

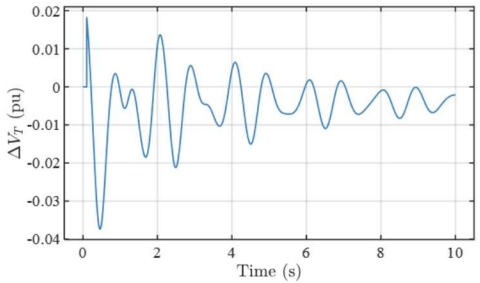


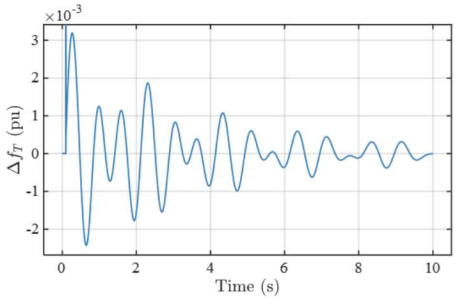


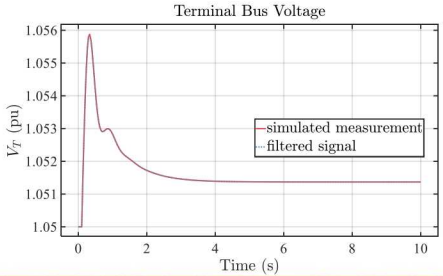
Simulation Results I

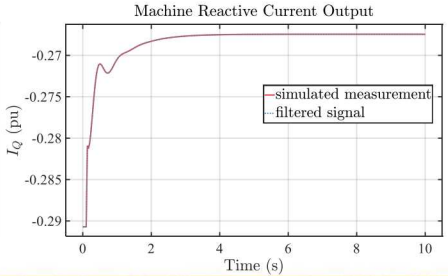


- Simulated single-machine infinite-bus (SMIB) system
- 15% generation drop (G2)
- Sampled signals at 30 frames per second
- Pre-processing has no effect on simulated data







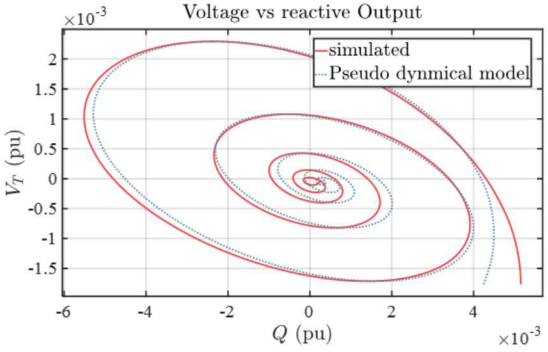


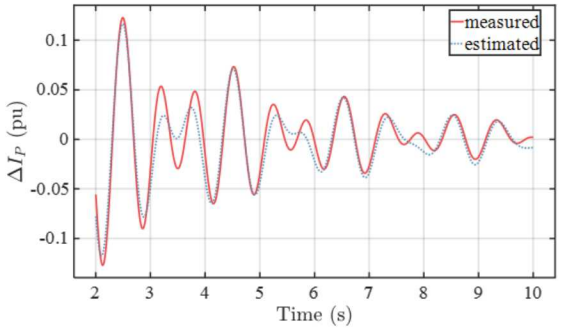
Simulation Results II

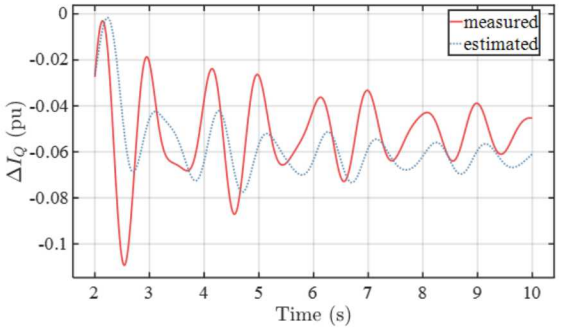
Resultant model matches reasonably well with the model reduction based approach

$$H_{Pf} = \frac{504}{1 + 0.989s}$$

$$H_{QV} = \frac{9.04}{1 + 0.769s}$$

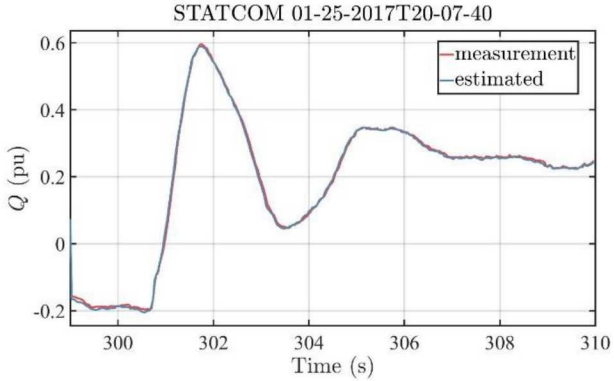


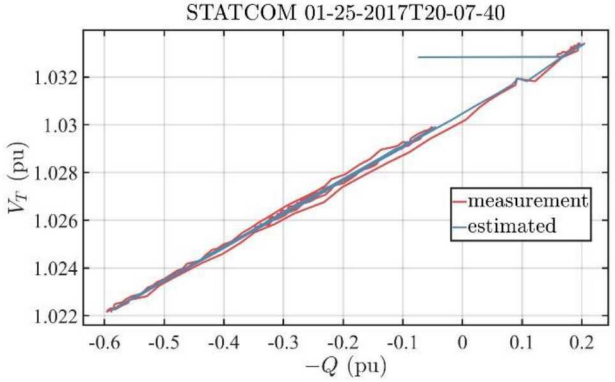




Results Historic Event Data STATCOM

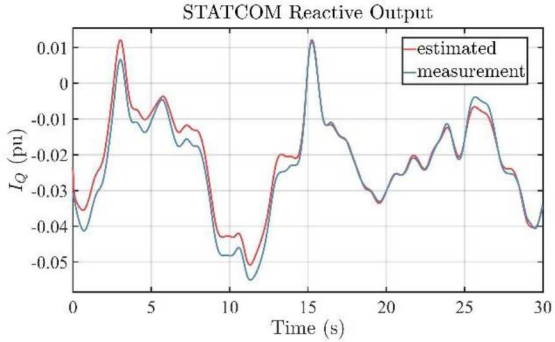
- 30 historic generator drop events
- STATCOM point of interconnection was monitored
- Resulting droop in all cases between 2.8 to 3.5 %





Results Historic Ambient Data STATCOM

- Ambient historic data
- STATCOM point of interconnection was monitored
- Resulting droop in all cases between 2.8 to 3.5 %
- Results are similar to results obtained from event data



Future Work and Conclusions

- Introduces a simplified dynamical model that can be used to evaluate control system performance
- The two approaches used to find the model match reasonably well
  - The signal based approach only requires POI measurements
- Future work
  - Use recorded PMU data to verify on real PMU measurements
  - Compare historic events to identify changes in generator performance