Generator Control System Performance Monitoring using PMU Measurements

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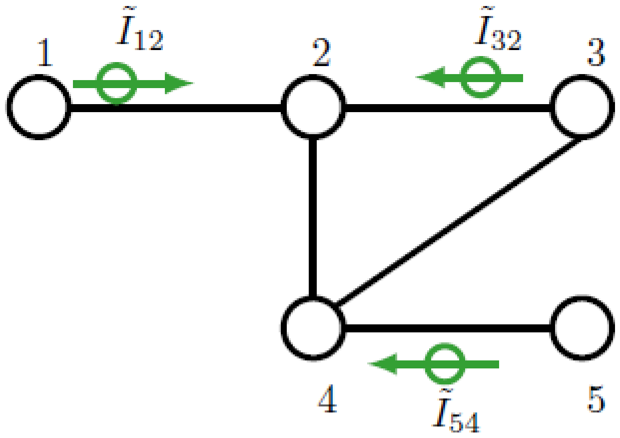
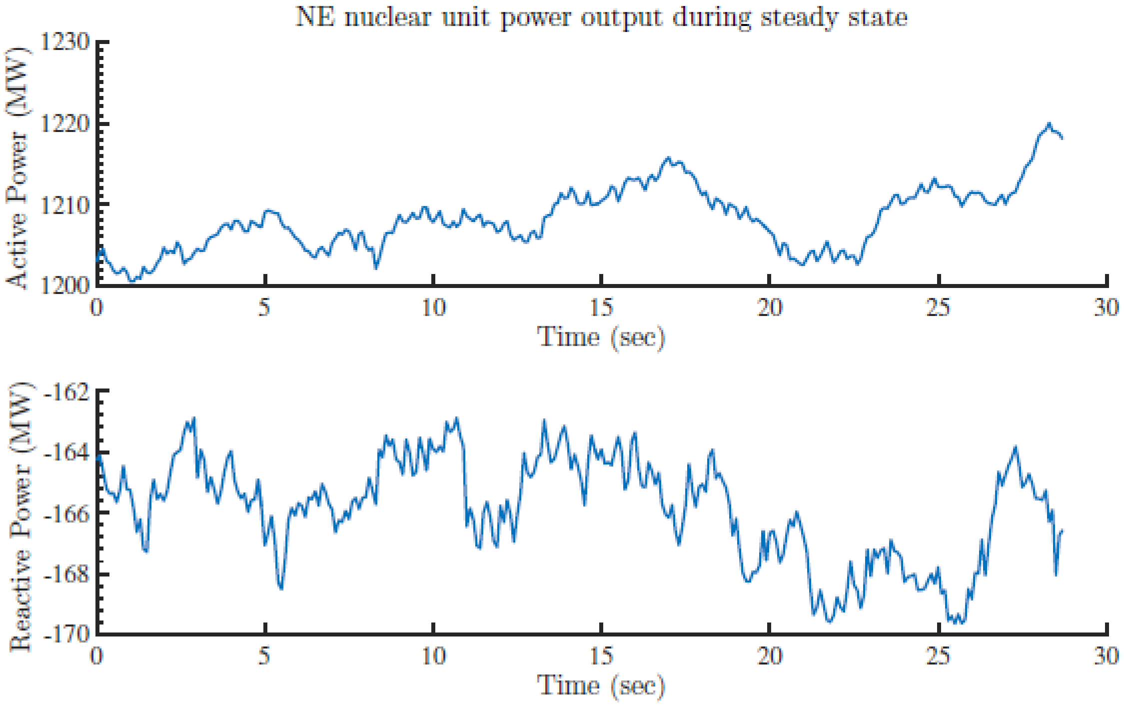
Overview

- 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.

Virtual PMU Measurements

- Methods require V and I PMU measurements from control system terminals.
- In case such measurements are not directly available, Virtual PMU data based on PMU state estimation can be used
- Implemented in RT at ISO-NE
  - Additional 29 Voltage Phasors
  - Additional 4 Current Phasors





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

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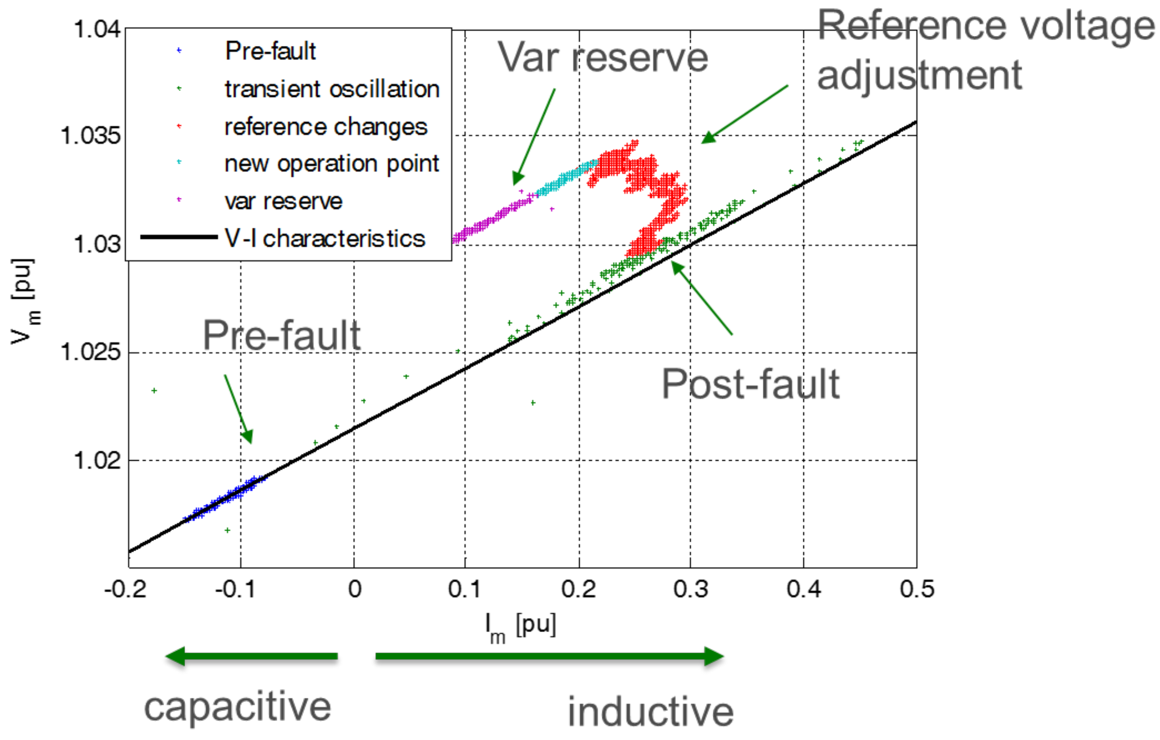
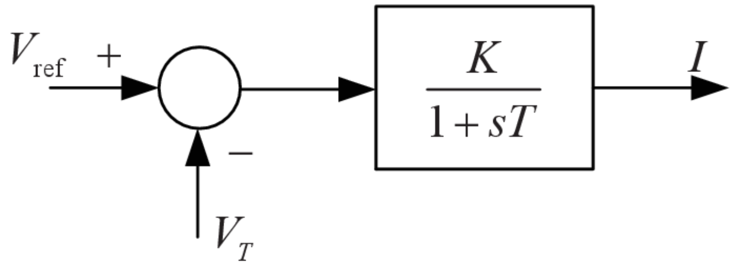
Generator Performance Goals

- 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 gain
    - a time
    - Simpler than full model parameter identification

Control Performance of a STATCOM

Example: PMU voltage and current measurement during and after a disturbance on a STATCOM

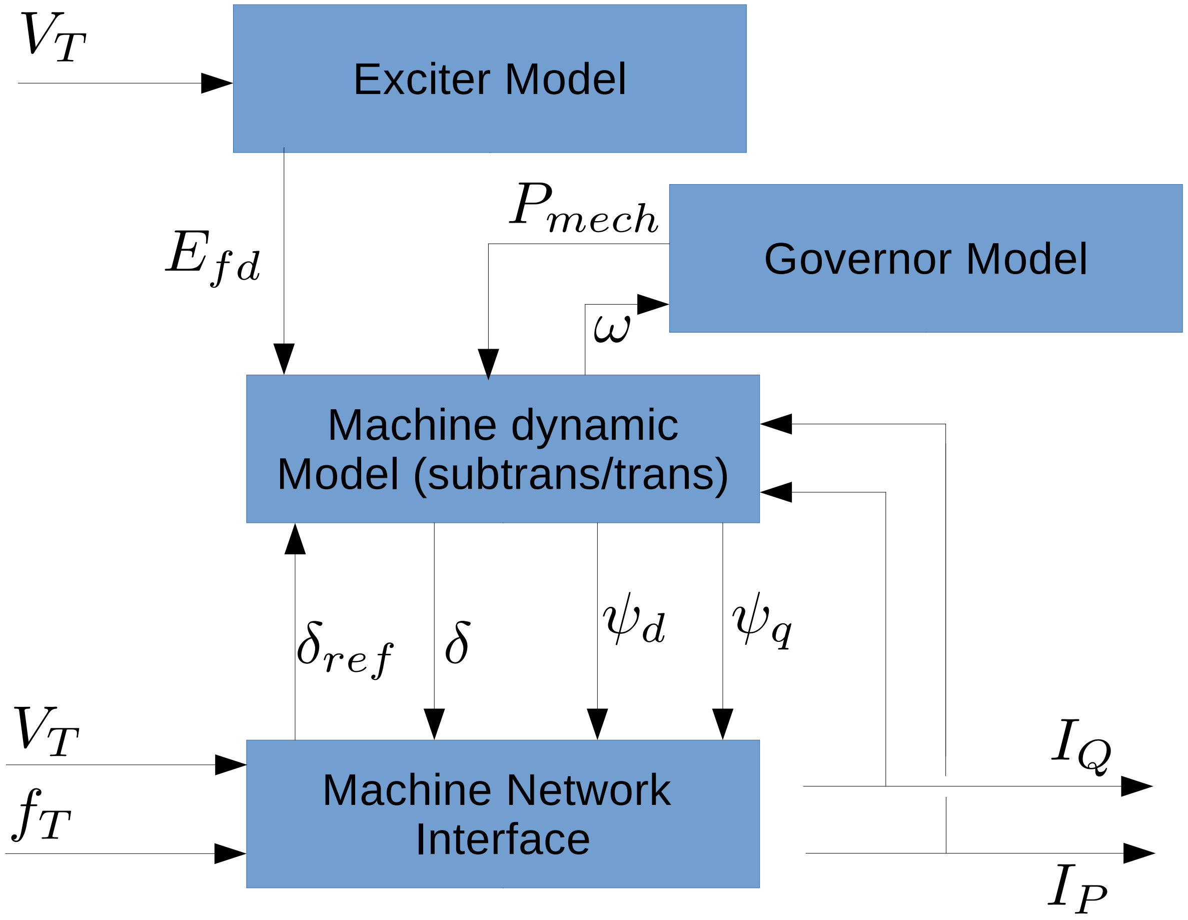




Estimated transfer function with K = 32.20=1/0.0311, T = 30.39 ms

Control Performance Theoretical Model

- Dynamic Model can be rearranged
  - Inputs from the Network
    - Terminal Bus Voltages
    - Terminal Bus frequency
  - Reactive and Active Outputs
    - Active Current
    - Reactive Current



Control Performance Theoretical Model

Separating the modes from the system shows a single Voltage Control Mode which can be monitored to evaluate Control Performance

Transfer function of the terminal voltage to reactive output current:

$$H_{VQ} = \frac{4.0816\big((s + 16.87)(s^2 + 7.06s + 12.76)(s^2 + 10.58s + 314.6)\big)}{(s + 20)(s + 7.541)(s + 0.4351)(s^2 + 12.42s + 323.4)}$$

Expanded Transfer function:

$$H_{VQ} = \frac{-15.0801}{s + 20} + \frac{-7.1691}{s + 7.541} + \frac{4.6434}{s + 0.4351} + \frac{-6.441s - 10.0158}{s^2 + 12.42s + 323.4} + 4.0816$$

Voltage Control mode

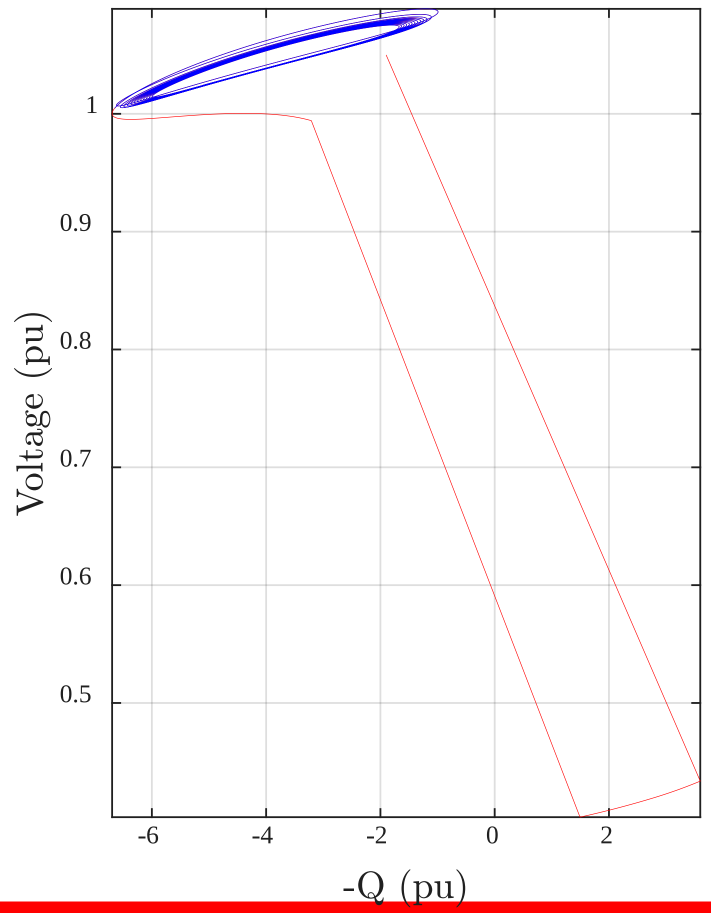
Transient model modes

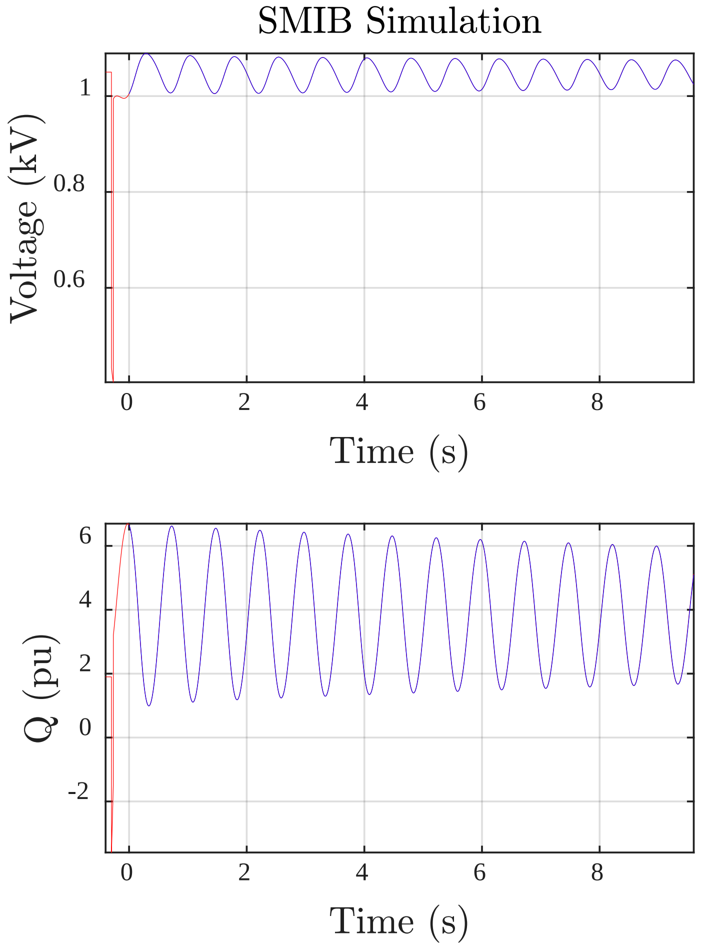
Oscillatory mode

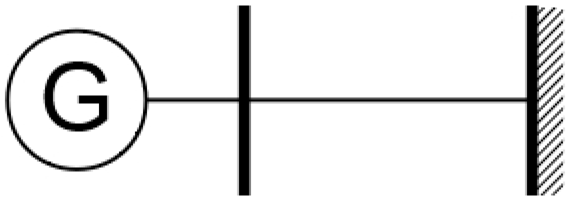
Feed through term

Control Performance Simulated Synchronous Generator

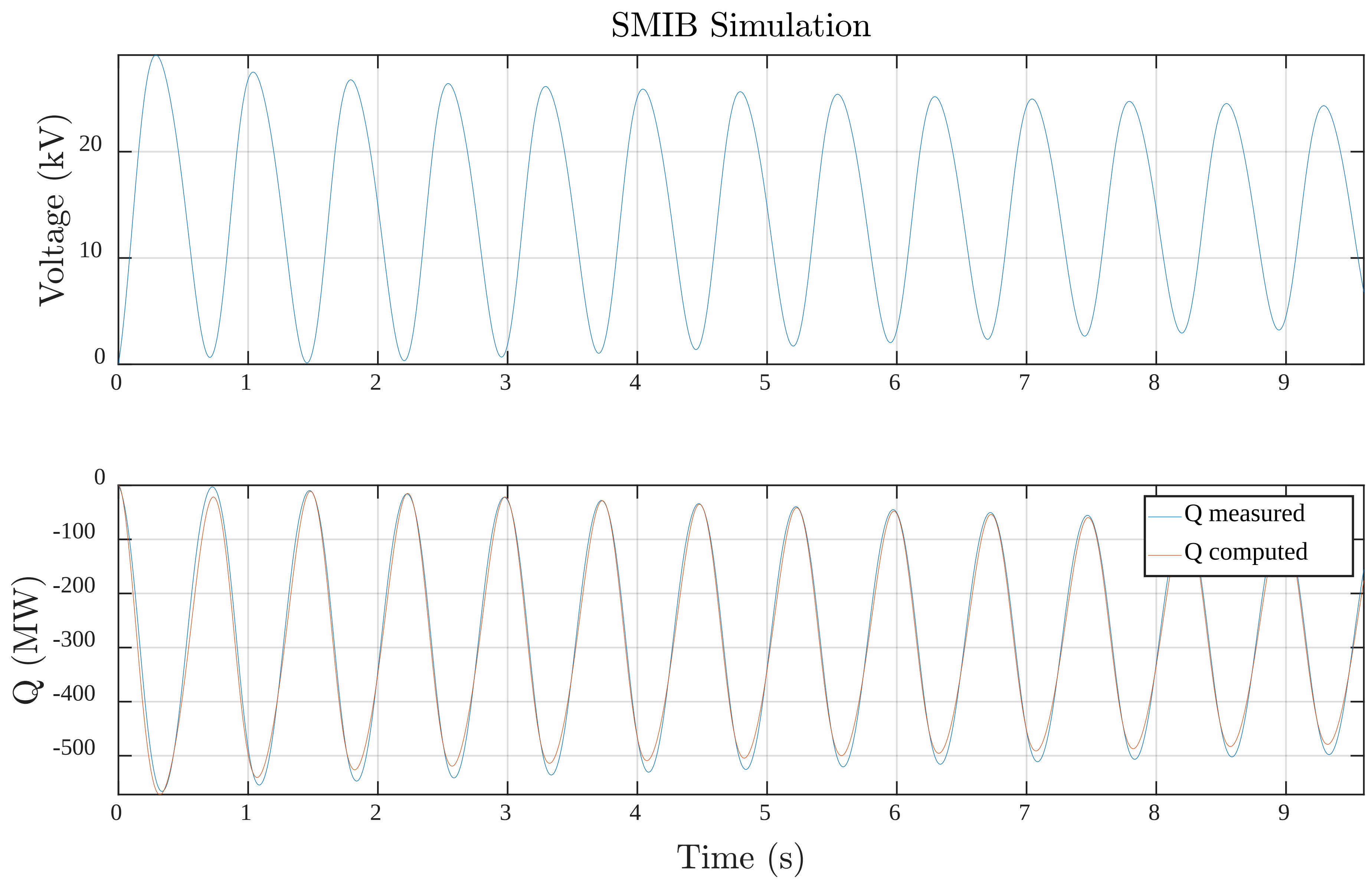
Example: Simulation of a generator subject to a disturbance in a single-machine infinite-bus system. Phase plot shows fault-on and post-fault trajectories. Use only the post-fault part.





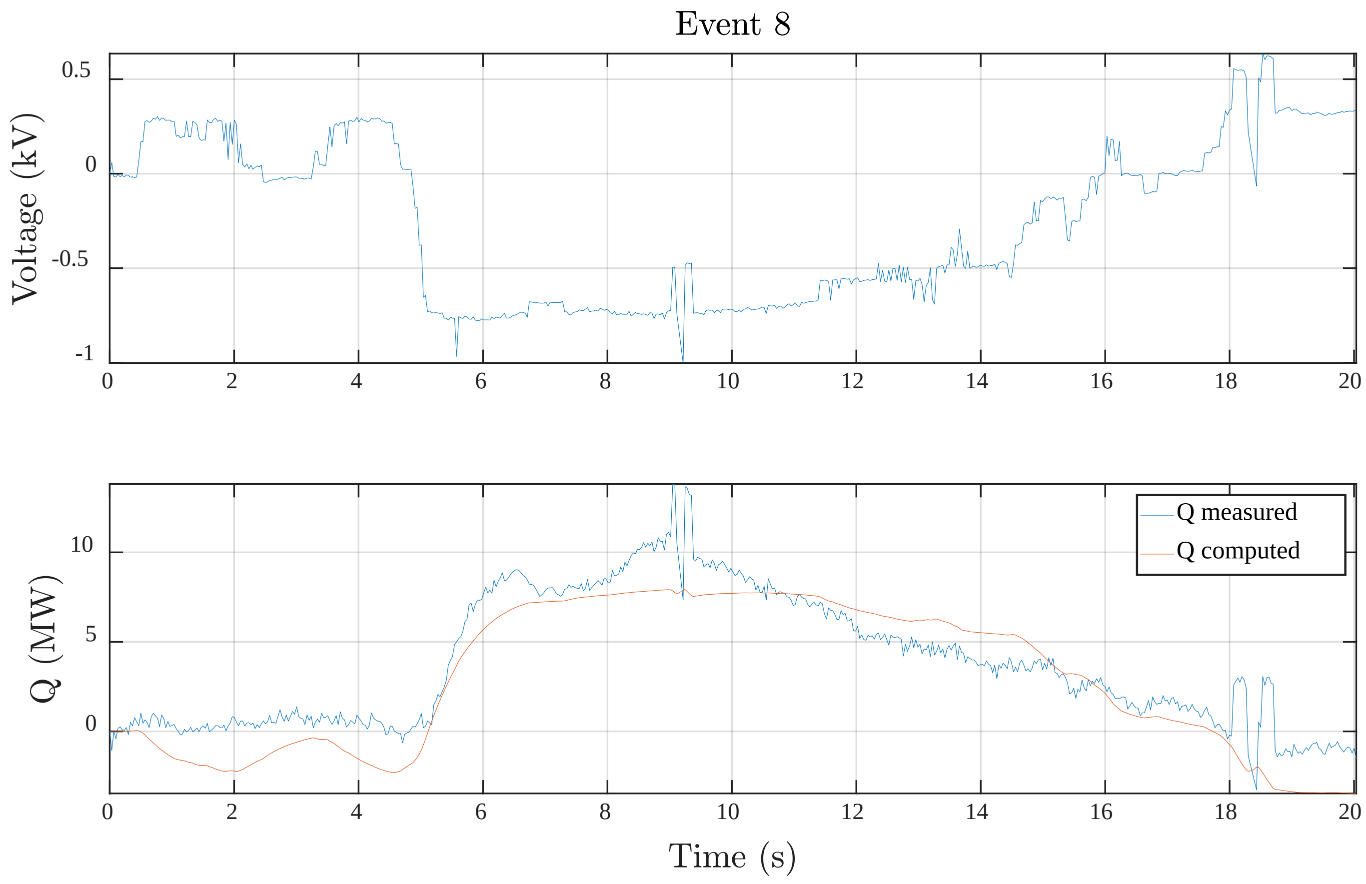


Control Performance Simulated Synchronous Generator



Control Performance Synchronous Generator

Example: PMU Measurement on a Generator during a fault in the Eastern Interconnection.



Control Performance Future Work

- Investigate the change in Control Performance during different events
- Investigate the use of ambient data
- Include the active power control performance evaluation
- Archive Control performance for historic data sets for comparison
- Develop performance monitoring software for RT deployment

Acknowledgements

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