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Input Signal for Synthetic Inertia: Estimated ROCOF Versus Remote Machine Acceleration

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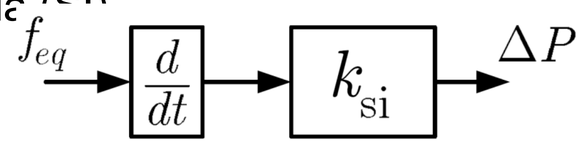
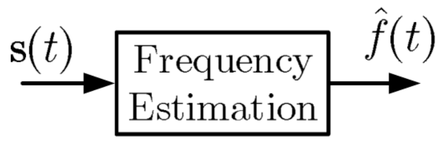
Background and Motivation

- Power systems dynamics are being affected by the increase in the installation of inverter-based resources (IBRs)
- In particular the installation of IBRs is causing a decrease in the inertia available in the power system, an effect that makes the system more vulnerable to power imbalance events
- To address this issue the common solution is to enable IBRs with a controller that emulates the inertial response of conventional generators. This type of control is known as synthetic inertia (SI)

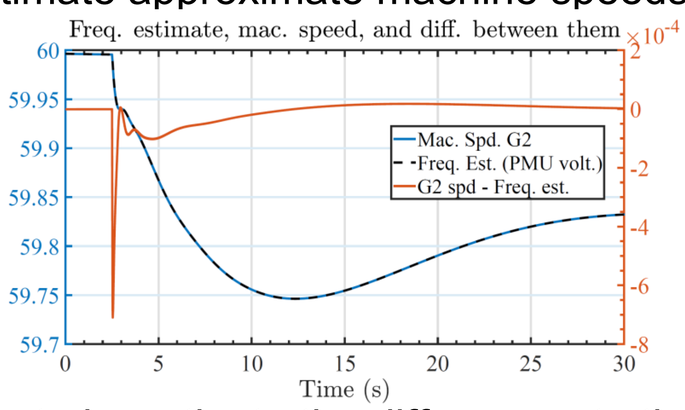


Block diagram of a SI controller

- Synthetic inertia controllers require the "local frequency" as the input signal. However, the estimation of frequency from *point-on-wave* voltages and currents is not a trivial task. The process of frequency estimation can be visualized:

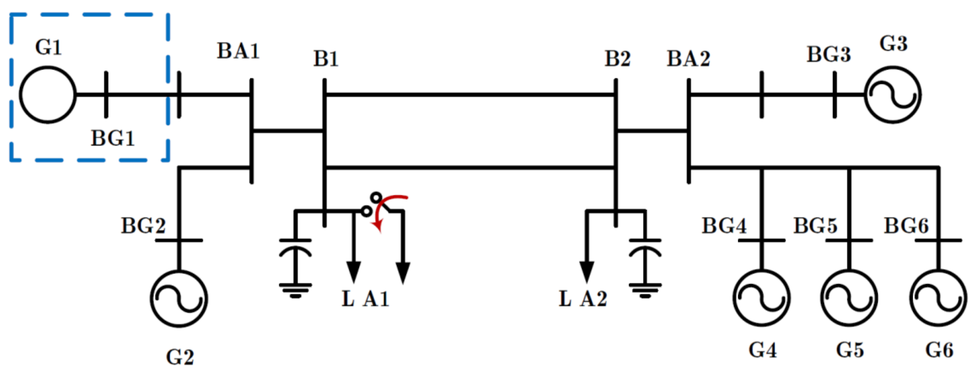


- The input signal **s**(t) is generally a one or a tree-dimensional signal.
- Multiple families of frequency estimation algorithms exists (DFTs, PLLs, Adaptive Notch Filters, Kalman Filters,…)
- Frequency estimate approximate machine speeds of nearby generators:



- This work aims to investigate the differences to the SI controller of IBRs between using a local frequency estimate vs a remote machine speed

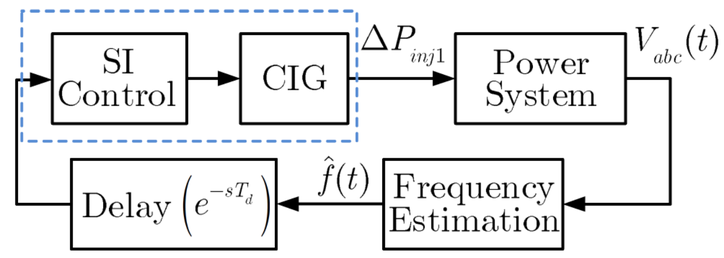
Test Power System



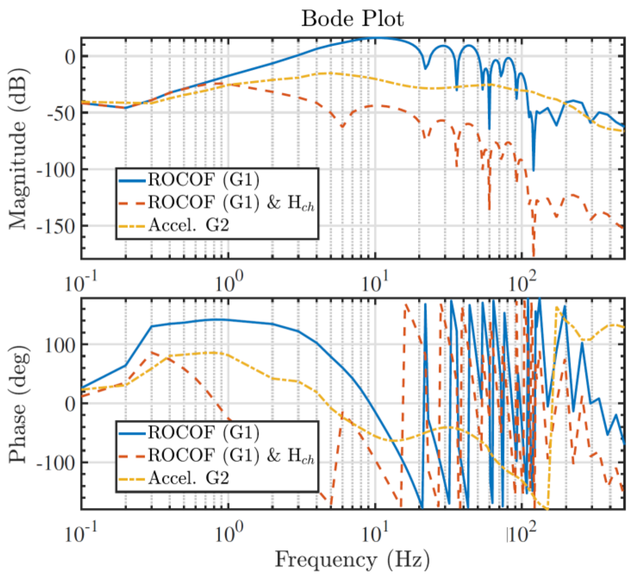
- Variation of the Kundur-Klein-Rogers (KRK) system
- IBR penetration of 25% (G1 was replaced by a generic IBR). The IBR had a SI controller attached to it. Two signals to drive the controller were used:
  - Machine speed of the nearby G2 conventional generator
  - Local frequency estimate using the DFT-based frequency estimation algorithm utilized by PMUs

SI Control Design and Results

- Block diagram of the control approach used in the work



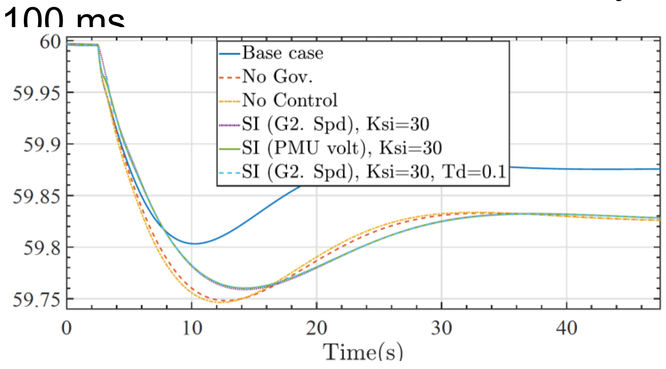
- In addition to the SI control a compensator was designed. A frequency domain approach was used for that task (the paper explores this in detail).



- Bode plots for the cases where the synthetic inertia controller is driven by the local frequency estimate out of voltage measurement with and without the controller of the form:

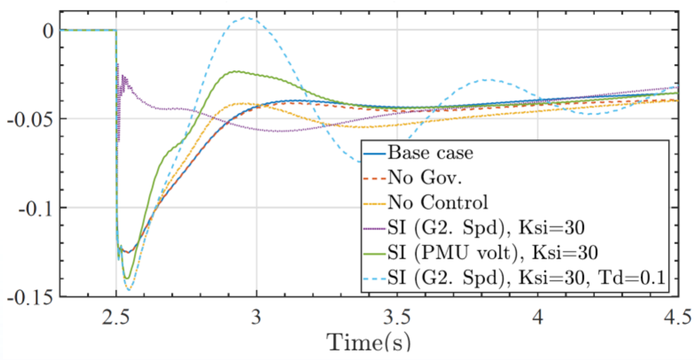
$$H_{ch}(z) = \frac{b_1 + b_2 z^{-1} + b_3 z^{-2} + b_4 z^{-3}}{a_1 + a_2 z^{-1} + a_3 z^{-2} + a_4 z^{-3}}$$

- Simulation results for an event that causes a 5% increase in load. Cases considered:
  - Base case, where G1 is a conventional machine
  - G1 is still a conventional generator without a governor
  - G1 is replaced by an IBR with no control
  - G1 is an IBR with SI control driven by the speed of G2
  - G1 is an IBR with SI control driven by the local freq. estimate (PMU algorithm)
  - G1 is an IBR with SI control driven by the speed of G2 with a delay of 100 ms



← System frequency

RoCoF →



Conclusions

- Synthetic inertial helps with the inertial response of the system
- Synthetic inertia control can be driven with local frequency estimates or nearby (but still remote) machine speeds
- With no delay machine speeds perform better than local frequency estimates but when delay is added local frequency has better performance

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