ABSTRACT

This project is focused on the fundamental research in establishing a foundational framework towards the development of an autonomous Cyber-Physical System (CPS) through distributed computation in a Networked Control Systems (NCS) paradigm. Specific attention is focused on an application where the computational, communication, and preservation challenges are unique due to the sheer dimensionality of the physical system. An example of such CPS is the smart power grid, which includes large-scale deployment of distributed and national Phasor Measurement Units (PMUs) and wind energy resources. The modeling adequacy study of such a system is performed. A systematic approach is proposed for wide-area oscillation damping control, which can handle data packet dropout in the communication channels in such smart power grids. The major challenges identified in the controller design are: a) computational burden, b) communication network delays and data dropout. The first is solved using frequency domain abstraction to reduce the dimension of the model. The latter is handled by exploiting the dynamic property of the reduced-order model (ROM) in an Observer-driven Reduced Copy (ORC) approach.

Proposed Tasks in the Program

1. Task 1: Modelling Adequacy Studies
   - A detailed subtransient model of the grid, which includes a modified model of the DFIG-based wind farm (WF).
   - A detailed characterization of the communication process with packet loss probability using Gilbert-Elliott model.
   - A model adequacy study for a Networked Controlled Power System.

2. Task 2: Frequency Domain Abstraction - Model Reduction
   - A novel Interpolatory iterative Rational Krylov Algorithm (IRKA) to reduce such models.
   - A demonstration of an improved accuracy with explicit preservation of the critical eigenvalues of original systems.

Key Contributions

1. Conventional grid with SGs (PS-SG): 2+2 MIMO system, 134 states, see Fig. 2.
2. Modern grid with inverter-based Wind Farms (PS-DFIG): 2+2 MIMO system, 167 states, see Fig. 2.
3. Larger Brazilian Interconnected Power System (BIPS): 4+4 MIMO system, the sparse descriptor system representation based on the unreduced Jacobian matrix has an order of 7,135 with 606 state variables and 6,256 algebraic variables.

Simulation Results: Communication Drop-out/resilient Control (ORC)

- Proposes performance measure I: on the basis of the norm of the difference between the system states and the reduced copy states in the inter-sample interval.
- Proposes performance measure II: based on the bound of the norm difference between the system state in presence of data dropout and that under ideal communication within an inter-sample interval.

- Useful for power system operators to perform online contingency screening and ranking from damping performance standpoint without running expensive time-domain simulations as a part of Dynamic Security Assessment (DSA).

Outreach Activities: Talks in Three ND Tribal Colleges

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