Title: Computing Framework for Distributed Decision Making to Ensure Robustness of Cyber-Physical Systems: The Case of the Electric Power Networks

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Contributing Faculty: Marija Ilic, Rohit Negi

Contributing Students: Yang Weng

Description:

1. Deterministic Modeling:

This work is motivated by major needs for accurate on-line state estimation (SE) in the emerging electric energy systems; voltage control particularly requires better voltage/reactive power state estimators. In this work we consider general state estimation challenges contributed by (1) the nonlinear nature of AC power flow equations and related numerical problems; (2) frequent equipment status changes causing network topology uncertainties and (3) poor measurement accuracy and overall bad data. A solution to problems (1) and (2) is proposed by formulating as a semidefinite programming (SDP) problem with the network topology changes explicitly modeled. We refer to the state estimators based on this approach as the convex relaxation-based state estimators. Our SDP-based SE formulation is also generalized to use phase angle measurements explicitly when these are available through PMU measurements. To utilize the cyber intelligent for robustness, we further present a new distributed algorithm for implementing SDP-based SE which preserves properties of the SDP-based centralized algorithm; the method is computationally manageable through parallel implementation in large-scale systems and is also robust to partial network failures. The proposed distributed algorithm comprises two steps: (1) decomposition of the large networks into much smaller network “cliques” which do not need extensive information exchange; and (2) each clique performs a Lagrangian dual decomposition-based computation and message passing within the clique.

2. Problistic Modeling:

This work is motivated by major needs for fast and accurate on-line state estimation (SE) in the emerging electric energy systems, due to recent penetration of distributed green energy, distributed intelligence, and plug-in electric vehicles. Different from the traditional deterministic approach, this paper uses a probabilistic graphical model to account for these new uncertainties by efficient distributed state estimation. The proposed graphical model is able to discover and analyze unstructured information and it has been successfully deployed in statistical physics, computer vision, error control coding, and artificial intelligence. Specifically, this paper shows how to model the traditional power system state estimation problem in a probabilistic manner. Mature graphical model inference tools, such as belief propagation and variational belief propagation, are subsequently applied.