Random transitions and eigenvalues for modeling demand and stability for the Smart Grid.

Analysis and Reduction of Complex Networks Under Uncertainty

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Abstract

We consider two aspects of uncertainty modeling associated with Smart Grid: demand and stability. Uncertainty in demand stems from fluctuations in both distributed generation as well as real-time transaction management and reflects limitations on predictability of a Markov chain model for demand. Uncertainties relevant to system stability are associated with fluctuations in renewable generation as well as demand. Under mathematically well defined conditions, these perturbations could lead to dynamical instability which may be a precursor to systemwide failure. The practical significance of these mathematical conditions is important for real-time management of SmartGrid resources. The poster will describe the two components of our modeling effort together with demonstration on computational models reflecting SmartGrid behavior.

Markov chain models are robust descriptors of many physical and natural behaviors. Their associated transition probabilities are typically calibrated to measured data and subsequently used for prediction. We have described these transition probabilities as radom matrices with random entries constrained to have their row-wise entries add-up to one (hence be stochastic matrices). We pursue a maximum entropy approach to develop a probability measure on the set of such matrices that is constrained to observed mean and standard deviation. We investigate the stationary behavior of this chain with random transition. The scatter in the transition matrices, as pursued in this effort, is a reflection of either modeling error, or data paucity. Modeling errors can be due to non-anticipative dynamics which may be perhaps associated with hysteretic effects reflecting aspects of social dynamics significant to the dynamics of the power grid system (which is a definite possibility under conditions of real-time pricing with feedback).

Perturbations to the dynamics of the powergrid can be associated with fuctuations in the generation of renewable energy (wind farms, PVC, etc) or fluctuations in demand. Understanding signatures of incipient instability under conditions of uncertainty in system parameters as well as system supply and demand is paramount to the capacity for pre-emptive intervention to localize failure and avoid systemwide failure. We have developed efficient agorithms for the computation of the dominant subspace in a random eigenvalue problem associated with the linearized dynamics of smartgrid. The resulting Jacobian has randomness due to the model parameters and state variables. A Polynomial Chaos representation for the Jacobian is calculated based on which the developed subspace iteration algorithm is used for eigenvalue analysis. The solution random eigenvalues can robustly describe the stability condition of the systems. The Polynomial Chaos representation will also facilitate the sensitivity analysis. Furthermore, the calculated random eigenvectors can be used in studying the time-history analysis the power systems under small perturbances.