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PROBABILISTIC METHODS FOR POWER GRID NETWORKS

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We employ a probabilistic framework to quantify uncertainty in computational modeling of power grid networks. We model power grid networks using a C++ "Electric power Grid Simulator (EGSim)" toolkit [2]. EGSim contains tools aimed at simulating both static load flow solutions, as well as nonlinear transient behavior. In addition to static models for generators and loads, it includes dynamic models for generators, faults, and breakers. The steady-state models result in a system of non-linear equations governing the power flow conservation at each bus. The transient models result in a system of Differential Algebraic Equations (DAEs). The toolkit employs a 2-nd order time discretization of the DAE system. Both steady and transient models are solved numerically using a Newton algorithm.

The properties of many operational and structural elements of power grid models are typically known to some degree of certainty: (1) grid topology and state, including knowledge of what lines are down, and what generators/loads are on line; (2) model parameters, such as generator/load/line electrical and performance characteristics; and (3) operational conditions, such as generator/load/line levels. In this uncertainty quantification (UQ) study we use probabilistic methods to model these uncertainties, estimate global sensitivity of model output observables to uncertain inputs, and obtain predictions with quantified uncertainty for steady state power grid solutions.

As an example, we will employ the standard 118-bus IEEE power grid model which consist of 54 generators and 64 loads. We proceed first with variance-based Global Sensitivity Analysis (GSA) [3] to rank load and generator parameters in terms of their contribution to the total variance of load flow solution for select power grid lines. Using the GSA results, we identify important parameters, and fix unimportant parameters at their nominal values, effectivelly reducing the number of uncertain inputs and the dimensionality of the forward-UQ problem.

We model uncertain quantities as random variables. We employ functional representations of these random variables in terms of sets of orthogonal basis functions of standard random variables, e.g. uniform or normal random variables. These representations, called Polynomial Chaos (PC) expansions [1], allow the efficient propagation of uncertainties from inputs to output quantities of interest. We employ a sparse quadrature approach to construct PC surrogates for quantities of interest as functions of the uncertain inputs of the power grid model. The accuracy of the surrogate, in the L_2 sense, is investigated with cross-validation methods.

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References

[1] R. Ghanem and P. Spanos. *Stochastic Finite Elements: A Spectral Approach.* Springer Verlag, New York, 1991.

[2] C. Safta, H. Najm, B. Debusschere, and R. Berry. Egsim - a C++ toolkit for analysis of power grid systems. Technical Report SAND2013-2838, Sandia National Labs, 2013.

[3] I. M. Sobol. Sensitivity estimates for nonlinear mathematical models. *Math. Modeling and Comput. Exper.*, 1:407–414, 1993.