Title : Theoretical foundations for finite-time transient stability and sensitivity analysis of power systems

Abstract:

Transient stability and sensitivity analysis of power systems are problems of enormous academic and practical interest. These classical problems have received renewed interest, because of the advancement in sensor technology in the form of phasor measurement units (PMUs). The advancement in sensor technology has provided unique opportunity for the development of real-time stability monitoring and sensitivity analysis tools. Transient stability problem in power system is inherently a problem of stability analysis of the non-equilibrium dynamics, because for a short time period following a fault or disturbance the system trajectory moves away from the equilibrium point. The real-time stability decision has to be made over this short time period. However, the existing stability definitions and hence analysis tools for transient stability are asymptotic in nature. In this thesis, we discover theoretical foundations for the short-term transient stability analysis of power systems, based on the theory of normally hyperbolic invariant manifolds and finite time Lyapunov exponents, adopted from geometric theory of dynamical systems. The theory of normally hyperbolic surfaces allows us to characterize the rate of expansion and contraction of co-dimension one material surfaces in the phase space. The expansion and contraction rates of these material surfaces can be computed in finite time. We prove that the expansion and contraction rates can be used as finite time transient stability certificates. Furthermore, material surfaces with maximum expansion and contraction rate are identified with the stability boundaries. These stability boundaries are used for computation of stability margin. We have used the theoretical framework for the development of model-based and model-free real-time stability monitoring methods. Both the model-based and model-free approaches rely on the availability of high resolution time series data from the PMUs for stability prediction. The problem of sensitivity analysis of power system, subjected to changes or uncertainty in load parameters and network topology, is also studied using the theory of normally hyperbolic manifolds. The sensitivity analysis is used for the identification and rank ordering of the critical interactions and parameters in the power network. The sensitivity analysis is carried out both in finite time and in asymptotic. One of the distinguishing features of the asymptotic sensitivity analysis is that the asymptotic dynamics of the system is assumed to be a periodic orbit. For asymptotic sensitivity analysis we employ combination of tools from ergodic theory and geometric theory of dynamical systems.