Pacific Northwest National LaboratoryLarge Deviation Theory for the Analysis of Power Tansmission Systems Subject to Stochastic Forcing

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We present an analysis of failure events in power transmission systems driven by random fluctuations in generation and load, such as fluctuations in wind power generation. For our analysis we employ a stochastic port-Hamiltonian model of power transmission and interpret failure events as escape events from basins of attraction across surfaces in phase space defined by security constraints. Using the Freidlin-Wentzell large deviation theory we derive closed-form, asymptotically valid, computable expressions for these failure rates as functions of the strength of the stochastic fluctuations and the state and properties of the network. These rates are validated against stochastic simulation for various reference power grid systems. These rates are then employed to constuct a Monte Carlo algorithm for simulating cascading failures in power grid systems. Finally, the stochastic properties of wind power generation are discussed.