Title: Risk-Based Security-Constrained Optimal Power Flow: Mathematical Fundamentals, Computational Strategies, Validation, and Use within Electricity Markets

Abstract: This dissertation contributes to develop the mathematical fundamentals and computational strategies of risk-based security-constrained optimal power flow (RB-SCOPF) and validate its application in electricity markets. The RB-SCOPF enforces three types of flow-related constraints: normal state deterministic flow limits, contingency state deterministic flow limits (the "N-1" criteria), and contingency state system risk, which depends only on contingency states but not the normal state. Each constraint group is scaled by a single parameter setting allowing tradeoffs between deterministic constraints and system risk. Relative to the security-constrained optimal power flow (SCOPF) used in industry today, the RB-SCOPF finds operating conditions that are more secure and more economic. It does this by obtaining solutions that achieve better balance between post-contingency flows on individual circuits and overall system risk. The method exploits the fact that, in a SCOPF solution, some post-contingency circuit flows which exceed their limits impose little risk while other post-contingency circuit flows which are within their limits impose significant risk. The RB-SCOPF softens constraints for the former and hardens constraints for the latter, thus achieving simultaneous improvement in both security and economy. Although the RB-SCOPF is more time-intensive to solve than SCOPF, we have developed efficient algorithms that allow RB-SCOPF to solve in sufficient time for use in real-time electricity markets. In contrast to SCOPF, which motivates market behavior to offload circuit flows exceeding rated flows, the use of RB-SCOPF provides price signals that motivate market behavior to offload circuit flows and to enhance system-wide security levels. Voltage stability testing has demonstrated that the dispatch result based on RB-SCOPF has higher reactive margins at normal state and after a contingency happens, thus has better static voltage stability performance.