Abstract:

        Voltage instability or voltage collapse, observed in many blackout events, poses a significant threat to power system reliability. To prevent voltage collapse, the countermeasures suggested by the post analyses of the blackouts usually include the adoption of better online voltage stability monitoring and control tools. Recently, the variability and uncertainty imposed by the increasing penetration of renewable energy further magnifies this need. This work investigates the methodologies for online voltage stability margin (VSM) monitoring and control in the new era of smart grid and big data. It unleashes the value of online measurements and leverages the fruitful results in machine learning and demand response.

        An online VSM monitoring approach based on local regression and adaptive database is proposed. Considering the increasing variability and uncertainty of power system operation, this approach utilizes the locality of underlying pattern between VSM and reactive power reserve (RPR), and can adapt to the changing condition of system. LASSO (Least Absolute Shrinkage and Selection Operator) is tailored to solve the local regression problem so as to mitigate the curse of dimensionality for large-scale system. Along with the VSM prediction, its confidence interval is also estimated simultaneously in a simple but effective way, and utilized as an evidence to trigger the database updating. IEEE 30-bus system and a 60,000-bus large system are used to test and demonstrate the proposed approach. The results show that the proposed approach can be successfully employed in online voltage stability monitoring for real size systems, and the adaptivity of model and data endows the proposed approach with the advantage in the circumstances where large and unforeseen changes of system condition are inevitable.

        In case degenerative system conditions are identified, a control strategy is needed to steer the system back to security. A model predictive control (MPC) based framework is proposed to maintain VSM in near-real-time while minimize the control cost. VSM is locally modeled as a linear function of RPRs based on the VSM monitoring tool, which convexifies the intricate VSM-constrained optimization problem. Thermostatically controlled loads (TCLs) are utilized through a demand response (DR) aggregator as the efficient measure to enhance voltage stability. For such an advanced application of the energy management system (EMS), plug-and-play is a necessary feature that makes the new controller really applicable in a coordinated environment. In this work, plug-and-play is realized by a coordinative interface strategy, which simplifies the representations of relevant controllers using the simple models declared, updated and fulfilled by those controllers. In particular, the customer dissatisfaction due to a sustained demand depression for DR is explicitly constrained to maintain the applicability of the control. IEEE 30-bus system is used to demonstrate the proposed control strategy.

        Adaptivity lies at the heart of the proposed approach. By making full use of real-time information, the proposed approach is competent at the tasks of VSM monitoring and control in a non-stationary and uncertain operating environment.