Abstract

The need for decarbonization has propelled the development of sustainable electric power systems with renewable and dispatchable distributed generators, energy storage systems, as well as demand response programs to promote consumer participation. The utilization of sustainable energy is facilitated by the deployment of independently controllable functional entities termed microgrids. The present thesis addresses the concerns associated with optimal planning and energy management in distribution systems and AC microgrids.

Network reconfiguration has been considered to be one of the classical methods of improving the performance of distribution systems from multiple perspectives. The present thesis harnesses static and dynamic reconfiguration with optimally-allocated distributed energy resources to implement planning and energy management in distribution systems. Peak demand curtailment by battery energy storage systems and distributed generators prolongs the infrastructure utilization, thereby deferring the need for feeder and substation upgrades. The deferral of the reinforcement of the relevant network assets enables the procurement of a substantial monetary benefit for the utility, which is modulated by the optimal allocation of batteries and distributed generators.

The present dissertation formulates stochastic, multi-objective, integrated sizing-scheduling models for distributed energy resources in AC microgrids. The multi-objective long-term resource sizing optimization is implemented using grey wolf optimizer in the fuzzy domain. The objectives are the minimization of the annual expenses, emissions, and energy loss, as well as the maximization of the annual monetary benefit due to the deferral of network upgrades. The microgrid planning models developed in this thesis are hinged on probabilistic power flow solutions, which incorporate the probabilistic modelling of the uncertainties in renewable power and load. Optimal hourly energy management strategies, based on price-based demand response programs, are designed for single and multiple interconnected grid-tied microgrids. Optimal power trade with the utility, as well as among interconnected microgrids, is regulated by price-based demand response. Optimal power dispatch is achieved in a droop-regulated islanded microgrid by optimizing the droop coefficients of the dispatchable distributed generators.

Keywords: Reconfiguration, distributed energy resources, battery energy storage system, upgrade deferral, droop-regulated islanded microgrid, multiple interconnected grid-tied microgrids, uncertainty, probabilistic power flow, multi-objective optimization, demand response, grey wolf optimizer.