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Enrollment No.: 2016EEZ8059

Abstract:

The research work presented in this thesis discusses various complex issues associated with distribution networks for their operations and planning. The existing approaches in this respect need significant revision, and thus the work in this thesis primarily aims at developing new efficient approaches to serve this need. The objective is to provide better methodologies for efficient and optimal operational planning of active distribution systems.

The upcoming demand and innovations like digitization, deregulation of power systems, integration of distributed energy resources (DERs), two-way power flow, new technical and business configurations, new players in the marketplace, privatization, and new technologies are compelling to advance distribution operations. However, the transitioning of traditional distribution architecture towards advance and smart active distribution system raises many technical challenges to the utilities. It makes the operations and planning of the distribution system operator more difficult and complex. This motivates the development of methodologies for efficient operational planning of distribution systems to achieve economical, secure, and reliable service.

Network reconfiguration is an important tool for the optimal operation of the distribution system. Depending upon the objective functions and constraints, it provides an optimal configuration of the network. The use of realistic voltage-dependent parameters is crucial in power system analysis and optimization. The impact of voltage-dependent load model on network reconfiguration is established in this thesis. Additionally, the impact of feeder bus/es voltage on network reconfiguration in the case of transmission-distribution coupled networks is also observed in this thesis.

The growing interest in renewable energy sources (RESs) is raising concern over their uncertain behavior. Installing storage devices (SDs) could be a viable solution to handle uncertainty. Moreover, future load and market/grid price are also uncertain and cannot be predicted accurately. Integrating RES and SDs poses more challenges to the operations of the distribution utilities, which demands an efficient modeling technique and framework considering the uncertainties. This thesis addresses the difficulty posed due to the mathematical formulation of SDs and distribution network reconfiguration (DNR), altogether, including the challenges associated with uncertain parameters.

With the progress of competition among companies, the involvement of new market players, and new technologies and business configurations, strategies are needed by every participant/player to survive in the market. Players are needed to make decisions for the anticipated electricity market outcomes. For this, multiplayer power transaction problem is proposed in this thesis to find the Nash equilibrium state.

Within the distribution system operator (DSO) framework, there could be alternative arrangements to enable market participation by all entities, including privately owned DERs. In many cases, retailers and similar aggregating agencies facilitate this. Even before finalizing the modalities of the market at the distribution level, it is essential to know about the possible market outcome and its impact on the operational decisions of DSO and vice-versa. This thesis presents a simulation framework and associated case studies, where the market outcome and DSO's operational activities are carried out in tandem to establish a realistic and feasible outcome.

Further, the encouragement to deploy more renewable energy sources and storage devices (R&SD) is giving an opportunity to retailers to install their own DERs. In such cases, a market framework must be designed to maintain the rational behavior of an electricity market. This thesis has modeled the stated scenario for which simulation frameworks of the retail market are proposed considering R&SD owned by retailers in consideration with DSO's operations. The simulation results show the importance of optimal allocation of energy resources in association with rational competition within retailers.

The proposed methodologies have been extensively tested on multiple test systems and detailed discussions on case study results have been presented. The results of test systems illustrate the effectiveness of the proposed methodologies for better operational planning of the active distribution systems.