Decentralized stochastic optimization based planning of integrated transmission and distribution networks with distributed generation penetration

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Abstract

In a current power system, numbers of distribution networks are physically connected to a transmission network at different boundary buses. As the planning solution of one network significantly influences the decisions made by planners of other networks, the transmission and distribution networks should coordinate and cooperate with each other to design the entire power system in a secure and economic manner. Inspired by decentralized and hierarchical optimization theories, this paper proposes a coordinated decision-making framework to determine the planning scheme and scenario based generation schedule for integrated transmission and distribution networks (ITDNs) with the penetration of distributed generations (DGs). A stochastic bi-level hierarchy is presented to decompose the centralized optimal planning of ITDNs. The obtained subproblems for independent transmission and distribution networks are formulated and relaxed to convex models. An improved iterative solution procedure is developed by exploiting the cascaded structure of the problems. Theoretical analysis and numerical results demonstrate the convergence properties of the decentralized optimization algorithm. The proposed coordinated planning framework outperforms conventional independent methods by decreasing expansion investment and improving DG accommodation.

Keywords: Transmission network, Distributed generation, Decentralized optimization, Stochastic planning, Distribution

1. Introduction

The modern transmission and distribution networks are physically connected at substation buses. According to the conventional power flow direction, transmission networks are normally upper levels while distribution networks are usually lower levels. Thus, the transmission network can be regarded as a pseudo generation to the distribution network, and the distribution network can be simplified as a load injection to the transmission network, as shown in Fig. 1. However, as transmission and distribution networks are separately designed by independent system planners and distribution companies to protect privacy of data, there is the lack of coordination and cooperation between transmission and distribution network planning. The transmission system operator (TSO) separately operates the transmission network without information (e.g., power flow variation and potential control) from the distribution network. Similarly, the distribution system operator (DSO) operates the distribution network without any information from the transmission network. As a result, very limited interaction (e.g., voltage magnitudes and angles) can be shared at the boundary bus, currently.
The penetration of distributed generations (DGs) at different power and voltage levels has greatly changed the passive characteristics of conventional distribution networks and consequently introduces active distribution networks in the current power systems [1-3], as shown in Fig. 1. Numbers of problems, such as voltage violation, DG accommodation, line congestion and boundary power mismatch, associated with integrating DGs are difficult to solve using the current separate planning manner. The conventional equivalent models for loads and balancing challenges, should be considered in the future integrated planning approach [7]. Moreover, the power system planning should
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