A risk-based approach for modeling the strategic behavior of a distribution company in wholesale energy market

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In active distribution networks (ADNs), the distribution company (Disco) can meet its demand from distributed energy resources (DERs) besides trading energy with the market. Therefore, in the presence of these resources, operational flexibility of the Disco as a price-maker player in the market has been increased. To model this behavior, a bi-level optimization approach is proposed in which the operation problem of the Disco and the day-ahead market clearing process managed by the independent system operator (ISO), are considered as the upper- and lower-level problems. To deal with uncertainties of renewable energy resources and demand, the Disco's problem is modeled as a risk-based two-stage stochastic one where the Disco's risk aversion is modeled using the Conditional Value-at-Risk (CVaR) method. The resulting model is a non-linear bi-level problem transformed into a linear single-level one through Karush-Kuhn-Tucker (KKT) conditions and the dual theory. To investigate the effectiveness of the model, this paper has applied that on a 24-bus power system. Moreover, sensitivity analysis is done on the capacity of DERs in the distribution network as well as the risk parameter to show their effects on the decisions made by the Disco.

1. Introduction

1.1. Motivation and aim

Electrical energy consumption is increasing regarding the population growth, industrialization, urban development, changing the lifestyle, etc. To supply this, high investments in power systems’ generation, transmission, and distribution level have always been required which can be done by governments or private owners [1]. On the other hand, development of the power systems has many problems such as high power losses in power delivery section, environmental issues and so on. To solve these problems, distributed energy resources (DERs) consisting of distributed generators (DGs), renewable energy resources (RERs), energy storages (ESs) and demand side management have emerged in the power systems especially in distribution networks (DNs) which change them to active distribution networks (ADNs) [1]. In a smart grid environment, ADNs are smart networks in which new wide-spread applications have been implemented including delivering reliable and efficient power through demand response (DR), providing a capacity to integrate more RERs, ESs, and DGs into the network, having a comprehensive optimization, controlling, as well as the monitoring capabilities [2]. Moreover, due to the presence of various smart technologies, intelligent structure has been provided to prepare connection and interaction between the distribution company (Disco) and DER aggregators which increase their ability to participate in the wholesale, local energy and reserve markets [2,3].
The effectiveness of DR programs in the operation and planning problems and energy markets is clearly explained in [4]. ESs have been used to support voltage and frequency parameters and to transmit short-term power with high quality. The other applications of ESs are used to support voltage and frequency parameters and to transmit.

In traditional DN, the Disco purchases its required energy from the market and has no capability to change its demand when it participates in the market as a price-maker player. In the presence of DERs, the decision making framework of the Disco changes, so it can purchase its required energy from DERs besides purchasing power from the market [9–12]. Therefore, the Disco can change its demand and participate in markets with different bids/offers. This capability of the Disco to change its decision making in the presence of DERs can be introduced as its flexibility in decision making. Therefore, in both cases (with and without DERs), the Disco can participate in the market as a price-maker player [9–12]. However, when Discos are equipped with DERs, they act as prosumers with the ability of consuming and producing energy simultaneously. Since the Discos can change the market price by changing their roles from producers to consumers and vice versa, they have an impact on market equilibrium price in a different way from the conventional energy players i.e. the generation companies (Gencos) and retailers [10]. To describe this behavior, a hierarchical decision making framework is required and to model this framework, a bi-level optimization approach can be used, the various types of which are presented in [13,14]. Moreover, the uncertain behaviors of demand and REs provide new challenges for the Disco. The aim of this paper is to model the strategic behavior of a Disco in wholesale Day-ahead (DA) energy market in the presence of DERs.
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