Combined Heat and Power-Based Microgrids

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The microgrid has emerged to reduce centralized generation problems and make structural changes to power systems. Parallel operation of distributed generation (DG) units, combined heat and power (CHP) units, and energy storage in the microgrids reduces environmental pollution, operation costs, and increases the reliability of energy systems.

combined heat and power (CHP) microgrids
demand response program (DRP)
information gap decision theory (IGDT)
distributed energy resources (DERs)

1. Introduction

With increasing energy demand and greenhouse gas emissions, centralized energy generation systems change and require structural changes to meet the world's increasing demand for electricity [1]. CHP units provide both thermal and electricity energy required by the consumers. This causes the CHP units to have more application in the microgrids; in addition, renewable energy resources are clean sources of energy, which find a special role in the emerging microgrids. However, one of the inherent characteristics of renewable energy resources is power generation uncertainty. Therefore, energy storage equipment in the microgrid that can store energy at intervals with high levels of available renewable resources and deliver it to the microgrid in intervals where the energy output of these sources is not sufficient is needed. Therefore, storage systems play a major role in reducing the impacts of the inherent uncertainties of renewable energy sources in the microgrid.

2. Management and Scheduling of Distributed Generation Units (DGs)

The management and scheduling of DGs, including renewable energy sources, has been the subject of much research [2][3][4]. For example, in [4] the scheduling and operation of islanded multi-microgrids using decentralized collaborative dispatch framework and multi-agent consensus algorithms were investigated. Regarding the inherent uncertainty of renewable energy sources, the problem of predicting wind speed and solar radiation has been studied in [5][6][7][8]. In [5], the evolutionary optimized local general regression neural network was used in order to predict wind speed and solar radiation. In [6], a stochastic scheduling model was proposed for CHP-based microgrids, by considering a periodic or seasonal pattern of load and price processes in the scenario generation procedure by ARIMA models. In [7], an adaptive modified firefly algorithm was used to solve the renewable MG, by considering the uncertainty of load forecast error, renewable energy sources, and market price. In [8], the intraday rolling dispatch strategy for the off-grid CHP microgrid was proposed to overcome renewable energy sources' uncertainties. In [9], an intelligent microgrid energy management methodology is proposed by using fuzzy environment and consideration of the uncertainty of renewable energy sources, in order to minimize power losses and costs. In [10], a stochastic scenario-based model for uncertainty modeling of demand, power generation of wind turbines, solar cells, and electricity market prices was presented. In [11], the optimal microgrid operation including fuel cells and CHP units was studied via the particle swarm optimization (PSO) algorithm; it also examined the impact of different tariffs on electricity sales and purchases every hour of the day. In [12], a mathematical scheduling for the optimal operation of micro-CHP units in the microgrid was presented.

The role of demand response programs (DRPs) in scheduling of microgrids is inevitable. In [13], a general classification for types of demand side management was proposed. In [14], a scenario-based planning model was proposed for large-scale wind farms by considering voltage stability issues, using a project management approach. A method for managing the demand response energy of microgrid using a chaotic search PSO algorithm has been proposed in [15] which increases the profitability of DGs. The proposed model is based on mixed linear planning. A DRP for household consumers has been presented in [16]. A real-time pricing mechanism has been proposed in [17] for residential users. Additionally, a robust bidding strategy model was proposed in [18] for large utilities, via DRPs.

In comparison with other robust optimization techniques, IGDT does not need to determine the maximum uncertainty radius for uncertain parameters, as the uncertainty radius is maximized by it [19]. In [20], IGDT has been employed to help grid operators in choosing appropriate power generation units to respond to variable demand. In [21], IGDT was used to minimize costs by considering wind energy uncertainty. In [22], IGDT was used to identify the optimal purchasing strategy from existing resources, with the aim of being robust against high cost. In [23], the uncertainty in the electricity market was examined using IGDT. In [24], a game theory-based model was proposed to assist the distribution grid operator in choosing trusted sources for grid demand response. In [25], a method for obtaining the tender strategy in the electricity market for large consumers using the IGDT was proposed. Information gap decision theory (IGDT) has gained the attention of various research works in the recent literature to handle severe uncertainties in various scheduling and operation problems of energy systems.

3. Conclusions

We proposed a robust day-ahead scheduling model for CHP-based microgrids at the presence of severe uncertainties of renewable energy sources. A RA strategy based on IGDT technique is developed aiming to determine the maximum allowable uncertainty radius for the output power of renewable energy sources, for a predetermined limit on the reduction of the revenue of all participants in the microgrid energy supply. The conclusions are summarized as follows.

- For a given level of β, i.e., β = 0.4 the uncertainty radius, i.e., α is obtained to be 0.34. This means that, with the consent of the 40% reduction in the objective function relative to its base-case value, at least 66% of the predicted amount of power generation by renewable energy sources could be available.

- By considering random variations of uncertain parameters based on their corresponding PDFs, via MCS trials, it is observed that the obtained schedule for the microgrid is robust for the determined radius of uncertainty.
- The robust schedule of the microgrid is obtained without any information regarding the nature and behavior of uncertain parameters, e.g., their PDF.
- Additionally, despite the other methods for uncertainty handling, such as MCS and scenario-based stochastic modeling, the IGDT does not add any computational complexity to the scheduling problem of microgrids.

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