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論文要旨

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要旨 (英文 800 語程度)

Thesis Summary (approx.800 English Words)

The past few decades have witnessed an increasing penetration of variable renewable energy (VRE) generation in power systems worldwide owing to its environmental and economic benefits. Furthermore, to enhance the flexibility of power systems, the use of demand response has grown as well. However, the inherent uncertainties of VRE generation and demand response pose challenges in addressing many power system planning problems. Among such is the unit commitment (UC) problem to determine the operating status of dispatchable power sources including fossil-fuel generators on the following day. As its main contributions, this dissertation proposes three UC models based on robust optimization for power systems under the uncertainty of VRE generation or that of demand response. The significance of the proposed models is that they optimize worst-case performances of such power systems in less conservative and more generalized ways than existing models.

The first proposed model considers a power system of fossil-fuel generators, battery energy storage systems (BESSs), loads, and VRE generation systems under the uncertainty of VRE generation. Its objective is to minimize the worst-case total operating cost for a set of VRE generation scenarios. To this end, the model assumes more than one decision-making stages, or more specifically, one day-ahead and multiple real-time stages. At the day-ahead stage, the operating range of each power source at each time period of the planning horizon is determined with the operating status. At each real-time stage, the operating level of each power source is optimized within the predetermined range for the actual VRE generation. The model is formulated as a two-stage robust optimization problem and solved by the column-and-constraint generation (C&CG) algorithm. Simulation results show that this model is less costly than the existing model with the same objective, which uses an affine policy, when the scenario set is built using the interval prediction method. Meanwhile, this dissertation also provides two supplementary methods for the first proposed model to reduce the actual total operating cost. The first method minimizes the expected total operating cost for some preselected VRE generation scenarios with the worst-case total operating cost bounded by a specified value. The second method extends the operating range so that a more economical operating level can be chosen at each real-time stage.

The second proposed model considers a power system of fossil-fuel generators, BESSs, loads, and wind farms, among other VRE generation systems, under the uncertainty of wind power. Its objective is to minimize the worst-case total operating cost for a set of wind power scenarios. This model builds on the first

proposed model. Exploiting the fact that the uncertainty of wind power decreases over time, the second proposed model delays determining the operating range to achieve less conservative scheduling. With this aim, an intermediate decision-making stage, namely the intra-day stage, is introduced between the day-ahead and the first real-time stages. Consequently, the operating status, range, and level of each power source are optimized sequentially at the day-ahead stage, the intra-day stage, and each real-time stage, respectively, under different degrees of wind power uncertainty. The model is formulated as a three-stage robust optimization problem, for which no existing algorithm is applicable. To solve it, a suboptimal approach is developed, where a constraint is imposed on the operating range so that the transmission capacity constraint of the power system is ignorable. This approach reduces the three-stage robust optimization problem to a two-stage robust optimization problem, which is solved by using the C&CG algorithm. Simulation results show that this model outperforms the first proposed model when the wind power uncertainty is severe at the day-ahead stage but decreases greatly at the intra-day stage.

The third proposed model considers a power system of fossil-fuel generators and loads, where each load has an associated customer. To maximize the social welfare, i.e., the total utility of power consumption by the customers minus the total operating cost of the generators, any existing UC model may integrate a demand response program where each customer bids for their flexible demand. However, the utility, which is represented by a bid, is often uncertain. To deal with this uncertainty of demand response, the third proposed model assumes one day-ahead and one real-time stage, at the latter of which the bidding takes place. Its objective is to maximize the worst-case social welfare for a set of bidding scenarios. Compared with the existing model with the same objective, the third proposed model is novel in that it explicitly determines the winning status of each customer, i.e., whether or not to accept their bid. This enables modeling more general operational constraints in demand response. The model is formulated as a two-stage robust optimization problem whose second-stage problem has integer variables and an uncertain objective function. To solve it, the C&CG algorithm is applied in a nested fashion. Simulation results verify the effectiveness of the third proposed model.

備考：論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。

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