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Studies on stochastic unit commitment formulation with flexible generating units

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ABSTRACT

In recent years, restructured power system has emerged and renewable energy generation technology has developed. More and more different unit characteristics and stochastic factors make the unit commitment (UC) more difficult than before. A novel stochastic UC formulation which covered the usual thermal units, flexible generating units and wind generation units is proposed to meet the need of energy-savings and environment protection. By introducing a UC risk constraint (UCRC), many stochastic factors such as demand fluctuations, unit force outages, variety of energy price, even the stochastic characteristics of wind generation can be dealt with. Based on the theory of chance constrained programming (CCP), the UCRC, a probabilistic constraint is changed into a determinate constraint, and then the presented formulation can be solved by usual optimization algorithms. Numerical simulations on 4 test systems with different scales show that different UC schedules can be determined according to different stochastic factors and its calculation time is acceptable in the view of practical engineer.

1. Introduction

Probability-based reliability assessment approaches for power systems have been well developed for application in planning-related decision-making. However, it is not well recognized that capacity reliability or capacity adequacy is also important for operational decision-making, especially for the unit commitment (UC) problem.

Stochastic factors, such as the demand fluctuation and the outage of utility, are the main causes of capacity inadequacy during power system operation. In order to relieve the influence of these factors, most of the available methods [1–3] introduced spinning reserve constraint into UC formulation. The evaluation of the system spinning reserve is usually based on deterministic criteria, e.g. a fraction of demand, largest generator/line contingency or maximum on-line generation during the dispatch period. Such criteria have widely been used, including applications in the market environment, mainly because they are easy to be understood and implemented. However, deterministic approaches do not explicitly take into account the stochastic behaviors of system components, and in doing so a system faces different degrees of risk throughout the operation period. Although the probabilistic nature of reserve has been well understood for several decades, its integration into the dispatch/UC optimization has not been addressed until recently [4]. Some reliability assessment criteria, such as loss-of-load-expectation (LOLE) and loss-of-load-probability (LOLP), are used in planning problem are revised and introduced into UC formulation. Ref. [5] defines LOLE and expected-energy-not-supplied (EENS) explicitly in terms of UC and dispatch variables as well as forced outage rates. In [6], the generation system is classified into different system operating states, such as healthy, marginal, and at risk. The deterministic criteria are combined with the probabilistic indices to monitor the system well-being. In fact, due to the inherent complexity of UC problem, uncertainty assessment and reliability requirements of the power system were rarely covered in most studies.

System load uncertainty in the UC problem is first considered and well developed. In Refs. [7–10], possible future outcomes in demand are represented by a scenario tree. But it is characterized in Ref. [11] as inefficient because this method created numerous variables even for a small scenario tree. Ref. [12] uses a chance constrained programming (CCP) formulation for the UC problem assuming that the hourly loads follow a multivariate normal distribution based on the research results of [13–15]. In Ref. [16] load forecast errors are also be considered in UC formulation. In general, due to the regular fluctuation character and the independence on calculation process, the stochastic characteristic of load demand can easily be taken into consideration in UC formulation.

For the outage of units, the contrary is the case because the operation states of units are undetermined during the commitment process, which embarrasses the reliability assessment. A probabilistic index which is known as unit commitment risk (UCR) has

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