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ABSTRACT

The main objective of electric power dispatch is to provide electricity to the customers at low cost and high reliability. Transmission line failures constitute a great threat to the electric power system security. We use a Markov decision process (MDP) approach to model the sequential dispatch decision making process where demand level and transmission line availability change from hour to hour. The action space is defined by the electricity network constraints. Risk of the power system is the loss of transmission lines, which could cause involuntary load shedding or cascading failures. The objective of the model is to minimize the expected long-term discounted cost (including generation, load shedding, and cascading failure costs). Policy iteration can be used to solve this model. At the policy improvement step, a stochastic mixed integer linear program is solved to obtain the optimal action. We use a PJM network example to demonstrate the effectiveness of our approach.

Keywords: Security Constrained Economic Dispatch, Markov Decision Process, Mixed Integer Linear Program, Stochastic Programming

1 INTRODUCTION

In a pool-based electricity market, security constrained economic dispatch is the process of allocating generation and transmission resources to serve the system load with low cost and high reliability. The goals of cost efficiency and reliability, however, are oftentimes conflicting. On the one hand, in order to serve the demand most cost efficiently, the capacities of transmission lines and the cheapest generators should be fully utilized. On the other hand, the consideration of reliability would suggest using local generators, which may not be the cheapest but are less dependent on the reliability of transmission lines; a considerable amount of generation and transmission capacities should also be reserved for contingency use. A tradeoff between low cost and high reliability is thus inevitable.

In practice, the “optimal” tradeoff for all stakeholders is a complex problem, and the solution may vary depending on the chosen perspective of decision making. The N-1 criterion

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(Harris & Strongman, 2004; Ren et al., 2008), for example, lists all possible contingency scenarios that have a single component failure and requires that the system be able to withstand all of these scenarios. Various stochastic criteria have also been proposed. Bouffard et al. (2005a, 2005b) review some of the recent publications on the probabilistic criteria and propose a stochastic security approach to market clearing where the probabilities of generator and transmission line failures are taken into consideration.

This paper presents another stochastic approach to security constrained economic dispatch, which is able to study some important issues that have not been adequately addressed in the existing literature. First, cascading failures are taken into consideration. Although a rare event, the impact of a cascading failure could be tremendous. The 2003 North American blackout, for example, affected 50 million customers and cost billions of dollars (Apt et al., 2004). Despite the amount of investment and effort spent by engineers and policy makers, there has been evidence that the frequency of large blackouts in the United States from 1984 to 2003 has not decreased, but increased (Hines & Talukdar 2006). A great amount of research has been conducted on modeling, monitoring, and managing the risk of cascading failures (see e.g., Chen & McCalley, 2005; Talukdar et al., 2005; Hines & Talukdar, 2006; Mei et al., 2008). Zima & Anderson (2005) propose an operational criterion to minimize the risk of subsequent line failures, in which the generation cost is not being considered. We adopt the hidden failure model (Chen et al., 2005) and take both the probability and the economic cost of a cascading failure into consideration of power dispatch.

Second, in our model, the dispatch decisions are made for an infinitely repeated 24-hour time horizon, representing the power system’s non-stop daily operations, as opposed to several other studies (such as Bouffard et al. 2005a, 2005b) which only consider an isolated 24-hour period. The advantage of an infinite planning horizon is that the future economic cost of a potential contingency is not underestimated when compared with the immediate reward of taking that risk.

Third, the optimal policy from the MDP model provides the optimal dispatch not only for the normal scenario but also for all contingency scenarios. The solution for the normal scenario is the optimal pre-contingency preventive dispatch, whereas the solution for contingency scenarios yields the optimal post-contingency corrective dispatch. Song et al. (2000) use an MDP approach to study the bidding decisions of power suppliers in the spot market. Their model has a finite time horizon and transmission constraints are not taken into consideration. Ragupathi & Das (2004) use a competitive MDP model to examine the market power exercise in deregulated power markets, in which transmission lines are assumed to be perfectly reliable.

The remaining sections are organized as follows. In Section 2, we introduce the power dispatch problem and make necessary definitions and assumptions. The MDP model is formulated in Section 3, and the policy iteration algorithm is used in Section 4 to solve the MDP model. Section 5 demonstrates the approach with a numerical example, and Section 6 concludes this paper.

2 DEFINITIONS AND ASSUMPTIONS

2.1 Transmission Network

A set of nodes, $\mathcal{N}$, is connected by a set of transmission lines, $L$. The sets of nodes with demand for and supply of power are denoted by $\mathcal{D}$ and $\mathcal{S}$, respectively. Depending on whether there is demand for or supply of power, any node in $\mathcal{N}$ could belong to either $\mathcal{D}$ or $\mathcal{S}$, or both, or neither.

A direct current (DC) lossless load flow model is used here, which has been found to be a good approximation to the more accurate alternate current (AC) load flow model when thermal limit is the primary concern (Hogan, 1993; Overbye et al., 2004). This model is a special case of the network flow model with
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