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Generation and Transmission Expansion Planning Based on Game Theory in Power Engineering

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Abstract

The unbundling of power generation and transmission in the restructured power system makes the coordinated planning of power generation and transmission a new challenge for both generation and transmission enterprises. In this paper, a single-stage deterministic model is proposed to study the interaction of strategies between both enterprises, based on the game analysis of generation and transmission planning. Then, Cournot model is used to simulate the expansion strategies of generation and transmission enterprises. The equilibrium is obtained by using the Mixed Complementarity Problem approach. In addition, the proposed model is applied to a three-bus system, which verifies the feasibility of this model.

Key words: game theory; generation expansion planning(GEP); transmission expansion planning(TEP); optimization model; mixed complementarity problem(MCP).

1. Introduction

The optimization of coordination between GEP and TEP has always been a difficult issue in power system planning[1]. As for the power source planning, several considerations should be taken such as the correspondence between power supply and load, the transmission pattern and distance of the grid, the efficiency of transmission channel as well as the security and stability of grid structure during operation. Moreover, the smart grid will significantly change the operation mode of traditional power system, making the generation and transmission links progressively develop a flexible, diversified response mode. For the coordination between the two links will have an enormous impact on the security and operational efficiency of power system[2], they should not be considered separately. Therefore, to ensure the safe, reliable and economic operation of power system under the background of smart grid development, it is necessary to make full consideration of the coordination between the generation and transmission at the planning level.

The transmission expansion planning is thought to coordinate with generation expansion planning and the two plans are researched separately in traditional power planning. Hu Ye, Yu Haihong (2010) studied the transmission planning method to achieve the optimal system operation condition under several scenarios, and the results indicated that dynamic programming (DP) is the most common method for

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power generation planning[3]. Yang Bin, Yu Yuefeng, Du Jianjun (2009) used genetic algorithms (GA) to study the power generation expansion planning[4]. According to the properties of natural monopoly and social utility of transmission network, Zhang Wuyang, Yao Jiangang (2009) studied how to guide the power generation planning by determining power transmission expansion planning[5]. In this paper, game theory is introduced to research the GEP and TEP problems. Generation enterprises and transmission enterprises are considered as participants of the game respectively, determining their own planning by considering the maximum profits. Then the balance is obtained by the optimal complementary approach. As a result, the interaction between GEP and TEP is considered, thus to help develop a more rational power planning.

2. Game analysis of generation and transmission planning

2.1 The basic relationship of coordinated generation and transmission planning based on game theory

First, we use a dual-bus system to explain the basic relationship of coordinated generation and transmission planning based on game theory.

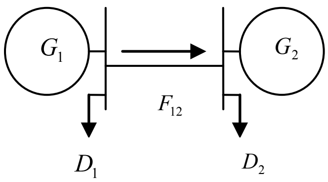

Fig. 1. dual-bus system

As shown in figure 1, node 1 and node 2 each has a power plant, namely G_1 and G_2. The electricity demands of node 1 and node 2 are D_1 and D_2 respectively, $D_1 < D_2$. Node 1 and node 2 are connected to a transmission line.

Assuming that the market price is based on nodal price, the generation cost of each node is a quadratic function, as shown in the formula (1).

$$Ci(P_{g,i}) = a_i + b_i P_{g,i} + \frac{1}{2} c_i P_{g,i}^2 \tag{1}$$

The marginal cost of power generation node *i* is:

$$MC_i = b_i + c_i P_{g,i} \tag{2}$$

MC_i is the marginal cost of power generation on node *i*. It can be seen as the price of node *i*, namely λ_i. Blocking gain from line *i* to *j* is shown in the formula (3).

$$CR_{ij} = (\lambda_j - \lambda_i) F_{ij}; F_{ij} \geq 0 \tag{3}$$

As it can be seen from formula (2), the node price λ_i is linear function of output power on this node. Price functions of node 1 and node 2 are drawn in figure 2.

Considering one extreme case, supposing that there is no transmission line between the two nodes, which means nodes 1 and 2 are independent. As shown at point A in figure 2 (a), all power generated by G_1 is given to D_1, and all power generated by G_2 is given to D_2. Then, the price difference between the