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Novel transmission pricing scheme based on point-to-point tariff and transaction pair matching for pool market☆

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ABSTRACT

Transmission pricing scheme is a key component in the infrastructure of power market, and pool is an indispensable pattern of market organization; meanwhile, pay-as-bid (PAB) serves as a main option to determine market prices in pool. In this paper, a novel transmission pricing scheme is proposed for pool power market based on PAB. The new scheme is developed by utilizing point-to-point (PTP) tariff and introducing an approach of transaction pair matching (TPM). The model and procedure of the new scheme are presented in detail. Apart from the advantages of existing transmission pricing schemes, such as ensuing open, fair and non-discriminatory access, proper recovery for investment as well as transparency, the new scheme provides economic signals to promote the maximum use of the existing transmission network, encourages appropriate bidding behaviors in pool, and helps to reduce the possibility of the enforcement of market power and the appearing of price spikes; thus improves market operation efficiency and trading effects. In order to testify the effectiveness of the proposed scheme, a case based on IEEE 30-bus system is studied.

1. Introduction

One of the most outstanding issues in the liberalization of power market is transmission pricing, which has significant impacts on the market efficiency. Transmission pricing scheme is a key component in the infrastructure of power market, ensuring open, fair and non-discriminatory access [1–4]. It is a challenging task to allocate the overall cost of transmission network among all users equally while provide them with correct, market-based economical signals at the same time [5]. In general, transmission pricing schemes appearing in the current literature could be classified into two basic philosophies: point-of-connection tariff scheme (POC) and point-to-point tariff scheme (PTP) [6,7].

The basic principle of POC is that market participants pay specific transmission fee according to the points they connect to in the network. The main advantage associated with POC is its simplicity. Transmission prices for each point are always pancaking of the local transmission costs on the principle of postage-stamp, which are public to all involved parties, including customers, generation corporations, load service entities and so on. POC is widely applied, as it could be either suitable for bilateral trading or pool competition. However, there are also distinct drawbacks of POC. On the condition of ignoring the actual status of system operation, POC tariff is not figured out according to the actual usage of the network, which means charges are independent of the distance and connection between the power source and the drain throughout. Hence, ineffective transactions would be approved while the payments for power delivery at POC tariff could not cover the transmission cost incurred by the transaction, which occupy plenty of transmission capacity and cause great transmission losses. Therefore, economical signals that generated by transmission pricing is distorted, resulting in reduction on market efficiency and trading effects [8].

Contrarily, the basic principle of PTP is that market participants pay transmission fee according to particular transaction pairs from named sellers to named buyers. PTP tariff is determined according to the augments of power flow in transmission facilities of the network caused by the transaction. By introducing PTP tariff in power trading, effective economical signals are generated and sent; participants will consider the distinctions of tariff for different transactions when making their decisions. Obviously, transactions with lower PTP tariff will be preferred, thus the maximum use of the existing system could be promoted [5,6]. In order to assess the actual usage of transmission network incurred by specific transactions, various effective methods have been proposed, such as MW-Mile, monetary path, contract path, counter-flow methods

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and so on [9–16]. However, PTP is not applied in pool market, as in which generation schedules are always determined unilaterally. Therefore, no transaction pairs like bilateral contracts are matched, and it's not necessary to clarify PTP tariff [17].

Pool is an indispensable pattern to power market, especially in short-term trading and real-time balancing mechanisms; while pay-as-bid (PAB) serves as a main option to determine market prices in pool competition [18,19]. As pool market is always organized oligopolistic-based, with inelastic demand, it is easy for participants to enforce market power, leading to price spikes and uplift in purchasing cost [9]. As transmission fee always accounts for a big proportion of transaction cost in power trading, it is taken into consideration when market participants are making decisions on trading strategies. In this case, transmission tariff could serve as a "tool" for the function of market regulation by sending correct economic signals to users of the network, promoting reasonable behaviors, effective competition and stable operation of the market [20,21]. However, since POC is always adopted in pool market, the function of market regulation is unavailable as economic signals disappear in the uniform POC tariff.

In this paper, a new transmission pricing scheme based on PTP tariff is proposed for pool market based on PAB. The new scheme is carried out along with the organization of pool market, while not interfere with the process of pool in order to keep its transparency. Bilateral transaction pairs are matched in sequence on the principle of achieving maximum utility incurred by the transaction pair, with utility representing buying price minus selling price and corresponding PTP tariff. In this case, the function of market regulation is developed as economic stimulation could be offered by the differences in rates of PTP tariff. In order to testify the effectiveness of the new scheme, a case of pool market based on IEEE 30-bus system is studied. For the sake of simplicity, the scheme proposed in this paper is denoted as TPM (transaction pair matching) scheme for short.

The paper is organized as follows: firstly, an introduction to pool market in China's power sector is depicted in Section 2; secondly, TPM scheme is described and formulated in Section 3; then, case study is done in Section 4; and finally, Section 5 provides the conclusion.

2. Pool market in China's power sector

Before deregulation in power sector, generators share the same capacity factors in an equal-dispatching way for production in China, ignoring the distinction of physical and economical characteristics among different generators. In order to introduce competition mechanism and improve operation efficiency, pool is adopted as an effective mode in the designation and organization of power market. Pool in China is always unilateral-based. Generators simultaneously submit power outputs and bidding prices before the opening of the market; then Market Operators (MOs) schedule the generators and dispatch the power outputs of those units that are scheduled on by the objective of minimizing the combined purchasing costs of all generation bidding.

PAB and uniform marginal pricing (MP) are main options to determine trading prices in pool market. Advantages and disadvantages for the two are compared and appropriately concluded in [18,19]; however, whether one or the other should be followed has still been subject for debate. Though MP is more common used worldwide, PAB is preferred in China. To date, PAB has been widely adopted in the transient period of China's power market, including the trial operation of Northeast China and South China regional power markets since 2005 and 2006, and the designation of power market at national and provincial levels, The reasons for the prevailing of PAB in China are explained as below.

China's national power market is organized monthly and weekly in pool mode, with provincial grid corporations and large generation corporations, for example, Generation Corporation of Three Gorges, being market participants. In order to promote effective transaction and enlarge trading volume, a certain proportion of total power consumption, like 10% or 15%, has to be offered as minimum compulsive trading volume for each involved province. As the distinctions in economic development levels among provinces in China are huge, it is not possible to utilize MP, as the uniform prices which seem reasonable to rich provinces may always be far beyond the affordable level of poor provinces. In this case, lots of complaints and debates will be incurred, thus hinders the evolution of deregulation. The same situation could be found in the regional power markets as well.

At the platform of province, power market is always oligopolistic-competition-based in supply side, leading to intensive market centralization. Moreover, the differences of production cost between various generators are huge and marginal units always belong to the oligopolistic corporations. Even worse, with the rapid increasing of power consumption in China, supply-demand ratio is low. In this case, if MP is utilized in pool market, it is quite easy for oligopolistic corporations to uplift clearing price by a slight holding back of available capacities; and it is hard for MOs to carry out effective regulation measurements. Therefore, market risks will be amplified and power purchasing costs will be increased. Besides, most of the power markets in China are organized in the mode of single-buyer. Grid corporations represent all customers covered locally; thus the demand-side is almost completely inelastic. Hence, PAB is in favor of as it is based on an average rather than a marginal price, and may be less volatile to gaming [18]. Furthermore, PAB is easily accepted as a pricing concept by no matter generation or grid corporations in China, as traditionally, the approved prices for generators vary a lot, which are set according to the integrated production cost of each unit.

As analyzed above, this paper focuses on the method to allocate the cost of a transmission network incurred by transactions in pool market among all participants. An effective transmission pricing scheme, TPM, is developed. Model and procedure of the TPM scheme are depicted and formulated in Section 3.

3. Depiction and formulation of TPM scheme

3.1. General description

TPM scheme mainly consists of three steps organized in sequence: forming primary PTP tariff matrix, transaction pair matching and transmission fee settlement.

PTP tariff reflect the actual usage of the network and transmission cost incurred by power delivery between the source and the drain throughout. By evaluating every possible transaction pair from generation point to load point in the network, a PTP tariff matrix is formed. Each element in the matrix represents the corresponding transmission price of delivering a unit of power production. It should be noted that in the first step of TPM scheme, the PTP tariff matrix is primary, which just represents the differential part of transmission fee while ignoring the basic part. Detailed explanations will be included in Section 3.2. The primary matrix is proclaimed to public before the opening of pool market.

After pool market is closed, trading results for participants are obtained, specifying generation outputs for every generator. Then, the step of transaction pair matching is carried out. This procedure is just introduced to decide the PTP tariff for each pair, not changing the trading results. Transaction pairs are formed in sequence one by one, by matching the possible pair that achieves the maximum utility, which represents buying price minus selling price and