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# A Review of Price Risk Management in PJM and Nord Pool Electricity Market

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**Abstract.** Market participants and system operators are faced with price risks caused by various factors, such as congestions or market power abuse. Therefore, the price risk management in deregulated market environment is of great importance. In this paper, various risk-hedge financial instruments in PJM and Nord Pool, such as FTRs, futures, forwards and CFDs are investigated. These risk management mechanisms can be further utilized for congestion revenue allocation, speculation or arbitrage under different market circumstances.

## 1. Introduction

In the past few decades, the restructuring of the electricity industry has proceeded rapidly around the world. The restructuring seeks to introduce competition in the electricity market, where electricity can be traded like other commodities, to improve economic efficiency [1]. Nevertheless, some challenges have been posed to the market participants, such as price risk management. In the regulated environment, the electricity industry is under a monopoly. These vertically integrated utilities charge consumers at a relatively stable electricity price [2]. In the deregulated market, electricity prices are mainly determined by the supply and demand situation. Extreme price spikes or volatility can be caused by uncertain factors such as weather, fuel price and transmission congestion in particular [3].

Congestion occurs when transmission limits are violated. To keep the reliability of power systems, it is necessary to re-dispatch generating units. In the vertically integrated environment where electric utilities are monopolized, the financial implications induced by such re-dispatch are not significant. The cost and revenue can be easily shifted among stakeholders. Nevertheless, in the deregulated power systems, generation companies are competing in an open environment to maximize profits. The re-dispatch caused by congestion may lead to the change in electricity prices and dramatically affects the participants' financial implications [4]. Furthermore, some strategic players may exploit the situation and exercise their market power to aggravate the congestion bottlenecks, thus increasing the uncertainty of electricity price. The deregulated market poses price uncertainty to electricity transactions, and market participants tend to employ some financial instruments to manage the price risks. Therefore, it is necessary to study risk management strategies in different markets.

In PJM, the main features characterizing its energy market are the implementation of locational marginal prices (LMPs) and the existence of Financial Transmission Rights (FTRs) [5]. FTR is a financial entitlement that enables the holder to receive revenues based on the day-ahead energy price differences across a specified transmission path. It enables market participants to hedge the nodal price difference. When transmission congestion occurs, the income charged from consumers is higher than



the expenditure paid to generators, resulting in the congestion revenue of regional transmission organization (RTO). FTR can be utilized as a strategy by RTO to allocate the congestion revenue.

In Nord Pool, market participants are faced with price risks of both zonal prices and system prices under the zonal pricing mechanism. The Nordic transmission grid was divided into several congestion zones. Each zone is an independent bidding zone and calculates its own zonal price. A system price in the Nordic market is calculated neglecting congestion [6]. Futures, forwards and Contracts for Difference (CFDs) are designed in Nord Pool financial market to hedge against the price risk.

The mechanisms of strategies of price risk management are not clarified clearly in previous researches. In this paper, strategies regarding settlement mechanisms, market environment and acquirements are studied. The paper is organized as follows: Section 2 introduces the pricing mechanisms and price risks under congestion in PJM and Nord Pool. Financial instruments such as FTRs, futures, forwards and CFDs are discussed in Section 3. In Section 4, the comparison of risk management strategies in PJM and Nord Pool is presented. Section 5 gives the conclusion of this paper.

## 2. Overview of Electricity Markets

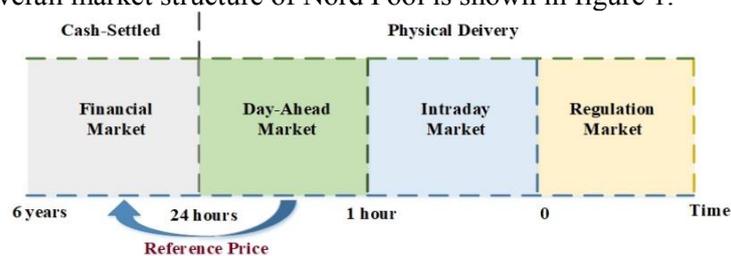
### 2.1. PJM

The PJM energy market is composed of a day-ahead market and a real-time market. The Day-ahead Market is a forward market to deal with offers, bids and bilateral transactions. The real-time market performs the actual system operations utilizing security-constrained economic dispatch (SCED). PJM utilizes LMPs throughout the trades. Sellers get paid with the LMP at their nodes for every MW produced, and the consumers get charged with the LMP at their nodes for every MW consumed. If the least-cost energy is available for all locations, the LMPs across the grid are identical. However, the transmission capacity is limited due to transmission constraints. If the power flow exceeds the transmission limits, congestion will be formed.

When the least-cost available energy cannot be delivered to load in a constrained area, higher-cost units in the constrained area must be dispatched. The re-dispatch results in the price of energy in the constrained area higher than the price in the unconstrained area. Load entities in the constrained area are charged higher, while generators in the constrained area will get the electricity fee at a lower price. Therefore, market participants face the price uncertainty raised by congestion. Besides, the transmission congestion revenue arises due to the unbalanced charge and expenditure of RTO.

### 2.2. Nord Pool

Nord Pool is composed of an energy market and a financial market. Nord Pool energy market consists of a day-ahead market, an intraday market and a regulation market. In the day-ahead market, bids and offers for delivery on the following day are cleared. Day-ahead prices are used as reference prices in the financial market. The intraday market deals with the trades close to real time, and the regulation market is a real-time market. In the financial market, various contracts are designed for risk management. The overall market structure of Nord Pool is shown in figure 1.



**Figure 1.** Market Structure of Nord Pool

In Nord Pool, zonal pricing scheme is adopted. TSOs have divided the market into several bidding zones. Each bidding zone has its own deficit, surplus of electricity and calculates its zonal price.

Producers and consumers sell/purchased electricity at the zonal price referring to their location. Besides, a system price of the Nordic Market is calculated based on the aggregated demand curves and aggregated supply curves, neglecting transmission constraints. Actually, transmission congestion can be problematic in the Nord Pool, resulting in the difference between zonal prices and system price [7]. These prices change all the time along with the variation of power supply and demand and congestion conditions. Confronted with the price uncertainty, market participants are exposed to trading risks and thus seek for risk management strategies to insure benefits.

### 3. Price Risk Management

#### 3.1. FTR – PJM

Based on the implementation of LMPs, PJM operates a FTR market to assist market participants in hedging nodal price risk. FTR is a financial entitlement for holders to receive a compensation based on the difference between sink and source prices. It provides a revenue stream for holders from the day-ahead congestion revenue to hedge against the price risk. Each FTR is defined with a specified direction in PJM transmission grid from a source point (with power injected) to a sink point (with power withdrawn).

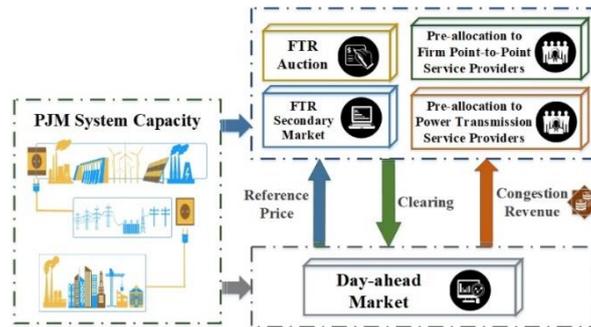
*3.1.1. Settlement Mechanism.* Supposing a power bilateral contract is signed of a volume  $Q_{Bic}$  specified with the source point  $i$  and sink point  $j$ .  $P_i$  and  $P_j$  are day-ahead hourly clearing prices of point  $i$  and point  $j$ , respectively. In the day-ahead market, the purchase cost at the sink point is the product of  $Q_{Bic}$  and  $P_j$ , and the electricity fee earned at the source point is the product of  $Q_{Bic}$  and  $P_i$ . Supposing a FTR is purchased for the same volume from the source point  $i$  to sink point  $j$ . The overall settlement is presented as follows:

$$\text{Congestion Cost} = Q_{Bic} \times P_i - Q_{Bic} \times P_j + Q_{Bic} \times (P_j - P_i) = 0 \quad (1)$$

FTR provides a revenue stream to hedge against the price difference exposed by LMP, which offsets the additional congestion costs in the day-ahead market, thus obtaining relatively stable nodal prices. The payment of RTO through FTR is equivalent to the FTR volume (MW) times the price difference (\$/MW) between the sink point and the source point in the day-ahead market, while the congestion revenue of RTO in the day-ahead market is equivalent to the transmission capacity (MW) times the price difference (\$/MW). The overall FTR volume issued by RTO does not exceed the transmission capacity. Therefore, the revenue collected from the day-ahead market is adequate and sufficient to pay for FTRs.

*3.1.2. Types.* Two types of point-to-point FTR can be acquired in PJM: FTR Obligation and FTR Option. Both FTR Obligation holders and FTR Option holders can benefit if the above difference is positive. The main difference between them is that FTR Option does not result in liability when the difference in the LMPs at sink point and source point is negative [8].

*3.1.3. Acquirements.* In PJM, market participants can acquire FTRs in the following mechanisms [9]: pre-allocation to firm point-to-point service providers and power transmission service providers, FTR auctions and FTR Secondary Market. Firm Point-to-Point Service is used for some transmission lines between control areas (power systems bounded by interconnection metering and telemetry). Power transmission service is used within a control area. PJM will allocate FTRs to these service providers at a fixed source point and a fixed sink point. The FTR capacity offered in auctions and FTR secondary market which is a bilateral system shall be the residual system capability. Figure 2 shows the relationship between the day-ahead market and FTR market.



**Figure 2.** The Relationship between Day-ahead Market and FTR Market

### 3.2. Futures, Forwards & CFDs – Nord Pool

In Nord Pool, the TSO does not issue transmission rights to market participants through congestion revenue like in PJM. Further analysis has exemplified that in the Nord Pool, the implementation of FTRs lacks the simultaneous feasibility and the congestion revenue is not adequate due to the zonal pricing scheme [10]. Instead, futures, forward and CFDs are utilized to hedge against the price risk caused by transmission congestion.

**3.2.1. Futures.** Futures are contracts for the delivery of a certain quantity of electricity at a specified price and a specified time in the future. Power suppliers can sell a proportion of their production in the future market, while consumers can buy a specific amount of the power they need. In this way, electricity can be traded at a risk-free price. The settlement of futures involves two steps: a daily mark-to-market settlement during the trading period and a settlement with reference to system prices during the delivery period. In the trading period, futures are subject to daily settlement with reference to the day-to-day changes in the closing price of the electricity futures. At the maturity of the contract, the delivery period starts, and a cash settlement takes place covering the difference between the final closing price of the futures contract and the system price during the delivery period [11].



**Figure 3.** The Settlement of Futures contracts

Figure 3 shows the settlement of the futures contract. Supposing a futures contract was signed at a predetermined price of 185 EUR/MWh. The price of assets continued to rise during the trading period and reached 223 EUR/MWh as the final closing price. The mark-to-market gain is 38 EUR/MWh accumulated by the daily settlement. During the delivery period, an additional revenue at the price of 2 EUR/MWh ( $225 \text{ EUR/MWh} - 223 \text{ EUR/MWh} = 2 \text{ EUR/MWh}$ ) was gained as a difference between the final closing price and system price. Therefore, the futures contractor purchases electricity at a price of 225 EUR/MWh in the spot market, and gain a profit at a price of 40 EUR/MWh through the contract, resulting in the actual purchase price of 185 EUR/MWh, equivalent to the contract price.

**3.2.2. Forwards.** Futures and forwards are similar in some aspects but different in the contractual structures, more importantly in the schedules of settlement. No settlement is performed during the trading period. The mark-to-market gains or losses are accumulated throughout the trading period. The

settlement will finally take place when the contracts reach their due dates. Forwards contracts also use the system price as the reference price. Futures and forwards enable the market participants to hedge against the system price risk. Furthermore, futures and forwards are open to speculators who want to “make a bet” on the price of electricity derivatives, making electricity transactions the same as other financial commodities transactions.

**3.2.3. CFDs.** In Nord Pool, generators are paid at the zonal price referring to their zone for their production, and customers purchase electricity at the zonal price in their zone. Therefore, futures and forwards are unable to hedge against the price risks when congestion occurs. To solve this problem, the CFD is designed as a hedging strategy with reference to the difference between the zonal price and system price. The calculation is presented as follows:

$$\text{Settlement of CFD} = Q_{CFD} \times (P_{zonal} - P_{sys}) \quad (2)$$

where  $P_{zonal}$  and  $P_{sys}$  are the average zonal price and average system price during the delivery period, respectively.  $Q_{CFD}$  is the contract volume. Once the zonal price is higher than the system price, the contract holder would receive a rebate. Otherwise, the holder would get charged.

**3.2.4. Hedging Strategies.** To hedge zonal price risks, market participants can purchase a CFD combined with a futures/forwards contract for a specified volume. Supposing a market trader expects an arbitrage of a volume of  $Q_H$  (MWH), and purchases a forwards contract at the price of  $P_{Forw}$  (EUR/MWH) with a CFD at the price of  $P_{CFD}$  (EUR/MWH) for the same volume. The overall cost can be calculated by the following equation:

$$\begin{aligned} \text{Cost} &= Q_H \times P_{zonal} - Q_H \times [(P_{sys} - P_{Forw}) + (P_{zonal} - P_{sys})] + Q_H \times P_{CFD} \\ &= Q_H \times P_{zonal} - Q_H \times (P_{zonal} - P_{Forw}) + Q_H \times P_{CFD} \\ &= Q_H \times (P_{Forw} + P_{CFD}) \end{aligned} \quad (3)$$

where the product of  $Q_H$  and  $P_{zonal}$  denotes the cost of electricity purchase in the spot market. According to equation (3), the ultimate cost is equivalent to the purchase costs of the forwards contract and the CFD. Furthermore, if market participants want to hedge against the price risk between different zones, they can purchase a CFD for delivery zone B and sell another CFD of the same volume for the generation zone A. In this way, the holders are able to hedge against the price difference at a fixed cost, presented as follows:

$$\text{Cost} = Q_{CFD} \times P_{CFD} + Q_{CFD} \times [(P_B - P_{sys}) - (P_A - P_{sys})] + Q_{CFD} \times (P_A - P_B) = Q_{CFD} \times P_{CFD} \quad (4)$$

where  $P_A$ ,  $P_B$  are zonal prices of zone A and zone B, respectively. The product of  $Q_{CFD}$  and zonal price difference between zone A and zone B represents the cost of electricity trades in the spot market.

**3.2.5. Acquirements.** Futures, forwards and CFDs can be acquired in the form of standardized contracts in NASDAQ OMX Commodities Europe [12].

#### 4. Comparison and Discussion

The comparison of FTRs, futures, forwards and CFDs are listed as follows:

- Settlement Period: The settlement of futures and forwards consist of a trading period and a delivery period, while the settlement of FTRs and CFDs only covers a delivery period.
- Asset Prices: The settlement of futures and forwards implies the underlying asset prices. The price of futures/forwards affects the ultimate revenue of the contract holders. Nevertheless, the price of the FTRs/CFDs has no influence on the settlement.
- Reference prices: The system price referring to the same location is taken by futures and forwards as the reference price. However, FTRs and CFDs take the prices between a pair of locations as reference prices.

- Usage: FTRs are commonly used as a hedge, while futures, forwards and CFDs can be used for hedging, speculation and arbitrage.
- Obligation or Option: FTR option holders can choose not to pay the liability caused by the negative price difference between sink point and source point. Nevertheless, FTR obligation, futures, forwards and CFDs are obligations once the contract is effected.

The techniques of price risk management are strongly coupled to the market design. To manage the price risks in a nodal-pricing market, FTRs can be utilized. For power markets where the zonal pricing are implemented, standardized futures, forwards and CFDs can be designed to hedge price risks.

## 5. Conclusion

A review on the price risk management in PJM and Nord Pool has been presented in this paper. The paper initially gives a brief introduction about the price risks in PJM and Nord Pool. Next, the settlement mechanisms, market environment and requirements of FTRs, futures, forwards and CFDs have been portrayed. Finally, comparison and discussion have been made. This paper is helpful for the construction of the financial market in China.

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