# Analysis Model of Electricity Purchasing Strategy for Electricity Retailers in Medium to Long Term Electricity Market

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**Abstract.** With the improvement of trading rules in the power market and the exploration of the potential for user side demand response, the role of power retailers in market transactions is becoming increasingly important. The current research on electricity retailers' purchasing plans mainly focuses on the risk avoidance of electricity retailers' multi market combination purchasing, lacking relevant research on the impact of user electricity consumption prediction errors and error adjustment methods on the cost changes of electricity retailers. This article proposes a profit calculation model and an electricity consumption prediction and adjustment model for power retailers. The power retailers are divided into conservative, general, and radical types, and the impact of the adjustment methods of power retailers for user electricity consumption prediction errors on the profits of power retailers is analyzed.

**Keywords:** electricity retail, medium to long-term contract trading, user electricity forecast, additional costs

## 1 Introduction

With the improvement of trading rules in the power market and the exploration of the potential for user side demand response, the role of power retailers in market transactions has become increasingly important. Currently, research on power retailers mainly focuses on the following two aspects.

In terms of purchasing strategies for power retailers, there is currently a large amount of literature that has developed purchasing strategies with the goal of minimizing costs or maximizing benefits. Reference [1] optimized the procurement cost, transmission cost, and penalty cost of bilateral contracts. Both references [2] and [3] aim to maximize benefits. In recent years, with the large-scale development of distributed energy, the main source of electricity purchasing business for electricity retailers has shifted to renewable energy electricity purchasing. Reference [4] considers the renewable energy quota system and establishes a flexible pricing model for electricity retailers that considers user demand side response. Reference [5] suggests that power retailers usually purchase most of their electricity from the medium to long term electricity market and determine prices in advance through bilateral

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negotiation contracts to avoid market risks. Reference [6] develops a computationally tractable two-stage stochastic mixed-integer optimization model to investigate the trading portfolio and risk optimization problem faced by retailers. In terms of electricity retailers' electricity sales plans. literature [7] aims to deal with the retailer's self-scheduling problem that aims to maximize their performance in both reserve and energy markets while minimizing their financial risks. Reference [8] designed a stepped incentive pricing model for electricity retailers selling electricity in the day-ahead market. Reference [9] designed five monthly retail packages, including time of use (TOU) pricing, day and night power bundling, and peak and valley penalty compensation. Reference [10] proposes that power retailers reduce electricity sales losses by developing demand response subsidy strategies during periods when the spot market electricity price is higher than its selling price. During the corresponding period, users determine the response electricity quantity based on the subsidy price set by electricity retailers to obtain additional profits.

The fundamental reason for the risk of electricity purchasing by power retailers is the risk of inaccurate prediction of proxy user electricity consumption, and the lack of relevant research on the impact of user electricity consumption prediction errors and error adjustment methods on cost changes of power retailers. This article takes medium to long-term contract transactions as the background and proposes a profit calculation model and electricity consumption prediction and adjustment model for power retailers. The power retailers are divided into conservative, general, and radical types, and the impact of the adjustment methods of power retailers for user electricity consumption prediction errors on the profits of power retailers is analyzed.

## 2 Calculation of medium and long-term contract transaction profit of electricity retailers

Assuming there is only one electricity retailers in a certain area, with four types of users: industrial, commercial, residential, and electric vehicles, all of which are powered by the seller. The calculation model for monthly electricity sales revenue of electricity retailers is:

$$A_m = \sum_{i=1}^{4} \sum_{j=f,p,g} (p_{ij} * q_{ij}) \tag{1}$$

Where $A_m$ denotes the revenue from electricity sales in month $m$ of the electricity seller, $m = 1, 2, \ldots, 12$ . $p_{ij}$ denotes the tariff level of the customer in the time period $j$ . $q_{ij}$ denotes the actual consumption of electricity by the customer $i$ in the time period $j$ . $i = 1$ denotes industrial customer, $i = 2$ denotes commercial customer, $i = 3$ denotes residential customer, and $i = 4$ denotes electric vehicle. $j = f$ denotes the peak period, $j = p$ denotes the usual period, and $j = g$ denotes the valley period.

Assuming that the monthly consumption of electricity by each type of user is predicted based on historical data, the model for calculating the cost of power purchase for the annual power contract and the next month's power contract between the electricity seller and the power plant is:

$$\begin{cases} C_{bm} = p_b \sum_{i=1}^{4} Q_i \\ C_{by} = \sum_{m=1}^{12} C_{bm} \end{cases} \tag{2}$$

Where, $C_{bm}$ denotes the monthly contracted power purchase cost. $C_{by}$ denotes the annual contracted power purchase cost. $p_b$ denotes the contracted power tariff, and $Q_i$ denotes the projected value of monthly consumption power for customer type $i$.

The real-time market cost calculation model for electricity retailers is:

$$\begin{cases} C_{rm} = \left( \sum_{i=1}^{4} Q_i - \sum_{i=1}^{4} \sum_{j=f,p,g} q_{ij} \right) * p_r \\ C_{rm} = \left( \sum_{i=1}^{4} \sum_{j=f,p,g} q_{ij} - \sum_{i=1}^{4} Q_i \right) * p_c \end{cases} \tag{3}$$

Where, $C_{rm}$ denotes the real-time market monthly cost, $p_r$ denotes the real-time market tariff, and $p_c$ denotes the compensation tariff, formula (4) denotes the real-time market cost under the forecasted power volume is greater than the actual power volume, and formula (5) denotes the real-time market cost under the forecasted power volume is less than the actual power volume.

The formula for calculating the real-time market electricity price is:

$$p_r = p_0 + \mu \Delta Q \tag{4}$$

Where, $p_0$ denotes the real-time market benchmark tariff. table $\Delta Q$ denotes the deviated electricity quantity. and $\mu$ denotes the elasticity coefficient of the impact of electricity quantity on tariff.

This yields a model for calculating the profit from the purchase and sale of electricity for the selling electricity provider:

$$\pi_m = A_m - C_{bm} - C_{rm} \tag{5}$$

Where, $\pi_m$ denotes the revenue from the purchase and sale of electricity by the electricity seller in a month $m$, disregarding other revenues and costs.

## 3 Contract Trading Model for Electricity Retailers

The feedback mechanism includes the following two loops.

Loop 1: Due to the predicted electricity quantity being higher than the actual electricity quantity, the total electricity quantity deviation increases, prompting the seller to reduce the predicted electricity quantity value, thereby reducing the electricity quantity deviation, forming a negative feedback loop for adjusting the electricity quantity deviation.

Loop 2: Due to the predicted electricity quantity being higher than the actual electricity quantity, the deviation in electricity quantity increases, leading to an increase in the penalty cost shared by the seller. This leads to the seller reducing the predicted electricity quantity and thus reducing the allocation cost, forming a negative feedback loop for the penalty factor.

### 3.1 Prediction module

In the forecasting module, the main consideration is the impact of each electricity seller's power forecasting plan on their respective share of the penalty cost. The forecasting of actual power is done using a stochastic function, which randomly generates actual power by setting a range of variation above and below a certain fixed amount of power. The formulas involved in the forecasting module are as follows:

$$l_{ai}.k = l_{pi}.k \times \left(1 + rand\left(-\sigma, \sigma\right)\right), i = 1,2,3 \tag{6}$$

$$e_{pi}.k = \frac{l_{ai}.k - l_{pi}.k}{l_{pi}.k}, i = 1,2,3 \tag{7}$$

$$e_{ap}.k = \frac{\sum_{i=1}^{3} abs\left(l_{ai}.k - l_{pi}.k\right)}{\sum_{i=1}^{3} l_{pi}.k} \tag{8}$$

$$c_0.k = e_{ap}.k \times \theta \tag{9}$$

$$\Delta c_i.j = c_0.j \times \frac{abs\left(l_{ai}.j - l_{pi}.j\right)}{\sum_{i=1}^{3} abs\left(l_{ai}.j - l_{pi}.j\right)}, i = 1,2,3 \tag{10}$$

$$c_i.k = INTEG\left(D \times \left(\Delta c_i.k - \Delta c_i.j\right), c_i.j\right), i = 1,2,3 \tag{11}$$

$$cs_i.k = smooth\left(c_i.j, delay\_time\right), i = 1,2,3 \tag{12}$$

$$\lambda_i.k = \frac{\Delta c_i.k}{cs_i.k}, i = 1,2,3 \tag{13}$$

Where, $l_{ai}$ denotes the actual power consumption of the seller $i$, $.k$ denotes the time point $k$, $.j$ denotes the time point $j$, $D$ denotes the period from time point $j$ to time point $k$, $l_{pi}$ denotes the planned power consumption of the seller $i$, $\sigma$ denotes the parameter of the range of variation of the actual power consumption, $e_{pi}$ denotes the deviation of the planned power consumption of the seller $i$, $e_{ap}$ denotes the deviation from the plan of total power consumption, $c_0$ denotes the extra cost caused by the deviation, $\theta$ denotes the penalty factor (unit cost of penalty cost), $\Delta c_i$ denotes the value added to the additional cost of seller $i$, $c_i$ denotes the cumulative value of the additional cost of seller $i$, $cs_i$ denotes the actual cumulative cost of seller $i$ due to the impact of information delays on the subsequent adjustment of the electricity quantity, and $\lambda_i$ denotes the percentage of the additional cost added to the seller $i$.

### 3.2 Adjustment module

In the adjustment module, considering the impact of the amount of shared costs and the magnitude of electricity deviation on the electricity retailers, the formulas involved are as follows:

$$l_{ri} = if\_then\_else\begin{pmatrix} \lambda_i \le \gamma, l_{pi}, if\_then\_else \\ \left(e_{pi} > 0, l_{pi} \times \left(1 + \pi_i\right), l_{pi} \times \left(1 - \pi_i\right)\right) \end{pmatrix}, i = 1, 2, 3 \tag{14}$$

$$e_{ri}.k = \frac{l_{ai}.k - l_{ri}.k}{l_{ri}.k}, i = 1, 2, 3 \tag{15}$$

$$e_{ar}.k = \frac{\sum_{i=1}^{3} abs\left(l_{ai}.k - l_{ri}.k\right)}{\sum_{i=1}^{3} l_{ri}.k} \tag{16}$$

$$c_0^{'}.k = e_{ar}.k \times \theta \tag{17}$$

$$\Delta c_i^{'}.j = c_0^{'}.j \times \frac{abs\left(l_{ai}.j - l_{ri}.j\right)}{\sum_{i=1}^{3} abs\left(l_{ai}.j - l_{ri}.j\right)}, i = 1, 2, 3 \tag{18}$$

$$c_i^{'}.k = INTEG\left(D \times \left(\Delta c_i^{'}.k - \Delta c_i^{'}.j\right), c_i^{'}.j\right), i = 1, 2, 3 \tag{19}$$

Where , $l_{ri}$ denotes the adjusted amount of electricity by the seller $i$ to the forecasted electricity, $\pi_i$ denotes the adjustment range of electricity by the seller $i$ , $e_{ri}$ denotes the deviation of the adjusted amount of electricity by the seller $i$ , $e_{ar}$ denotes the adjustment deviation of the total electricity, $c_0^{'}$ denotes the additional cost due to the adjustment deviation, $\Delta c_i^{'}$ denotes the value added of the additional cost adjusted by the seller $i$, and $c_i^{'}$ denotes the cumulative value of the additional cost adjusted by the seller $i$.

The formula for calculating the impact of the sum of actual electricity sales by each seller on the electricity price in the real-time electricity market is:

$$p_{rm} = p_0 + \mu \sum_{k=1}^{n} \Delta Q_k \tag{20}$$

Where, $\Delta Q_k$ denotes the deviation of the electricity seller. The calculation formula for the cost change of electricity retailers in this scenario is:

$$\Delta C_{rm} = \left(p_0 + \mu \Delta Q_k\right) * \Delta Q_k - \left(p_0 + \mu \sum_{k=1}^{n} \Delta Q_k\right) * \Delta Q_k \tag{21}$$

Where, $\Delta C_{rm}$ represents the value of the change in the real-time market cost of electricity purchased by the seller $k$ .

From this, the calculation formula for the actual electricity purchase and sales profit of each electricity retailers company can be deduced:

$$\pi_m = A_m - C_{bm} - C_{rm} + \Delta C_{rm} \tag{22}$$

## 4 Example analysis

### 4.1 Parameter settings

Selecting user information from a certain region as the data basis for example analysis, the monthly electricity consumption statistics for the previous year in that region are shown in Table 1.

**Table 1.** Monthly Electricity Consumption Statistics of Various Users(kW·h)

| User class | Industry | Resident | Business | Electric Vehicle | Total |
|---|---|---|---|---|---|
| January | 1304507 | 46519 | 956700 | 4700 | 1142426 |
| February | 1206196 | 45761 | 1035480 | 4600 | 1212037 |
| March | 1305977 | 30259 | 926580 | 4800 | 1097616 |
| April | 1240029 | 20549 | 800880 | 4900 | 950358 |
| May | 1300400 | 21648 | 661560 | 4700 | 818308 |
| June | 1170171 | 43257 | 1083480 | 4720 | 1248628 |
| July | 1240715 | 43405 | 1141320 | 4530 | 1313970 |
| August | 1260849 | 35610 | 1132740 | 4570 | 1299769 |
| September | 1160956 | 59715 | 769860 | 4690 | 951221 |
| October | 1340639 | 50467 | 937980 | 4789 | 1127875 |
| November | 1266099 | 60137 | 1235460 | 4637 | 1426933 |
| December | 1310779 | 59137 | 899700 | 4790 | 1095406 |

The annual contract electricity price signed between the electricity seller and the power generation company is 0.45 yuan/kWh, the monthly contract electricity price is 0.48 yuan/kWh, the real-time electricity market benchmark electricity price is 0.7 yuan/kWh, the elasticity coefficient for deviating electricity is 0.005 yuan/MWh, and the compensation electricity price for deviating electricity is 0.3 yuan/kWh.

### 4.2 Analysis under different scenarios

In the scenario where there is only one seller, the seller chooses to judge the changes in electricity consumption in the next month based on the previous month's electricity consumption situation. Based on the seller's risk propensity characteristics, it is mainly divided into the following scenarios: Conservative electricity retailers, General electricity retailers, Radical electricity retailers.

**Conservative electricity retailers.**

In this scenario, the seller chooses to sign an annual contract based on the previous year's electricity consumption, without changing the monthly contract electricity quantity. Considering the stability and randomness of user electricity consumption, a random function is used to determine the electricity consumption situation for the next year. as shown in Fig. 1.

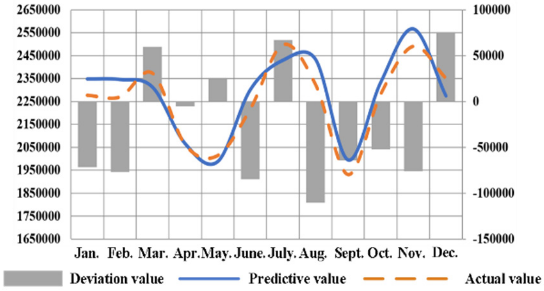


**Fig. 1.** Architecture of a typical wireless sensor node.

Power forecasting in a scenario that does not take into account changes in the power of the customer base shows a large deviation, with a maximum deviation of about 110 MWh. From this it is possible to calculate the extra costs and total costs for the year for the electricity seller as the more the deviation. The higher the real time tariffs incurred and the higher the extra costs, resulting in a double increase effect. Extra costs have a direct impact on the profitability of the electricity seller in each month. In some months, the percentage of extra cost to total cost is more than 7%, so the accuracy of power forecasting should be improved.

**General electricity retailers.**

This type of electricity retailers is common, which will fine-tune the electricity forecast for the next month based on the changes in electricity consumption in the previous month of the year. The predicted electricity consumption trend of this type of electricity retailers is shown in Fig.2 .

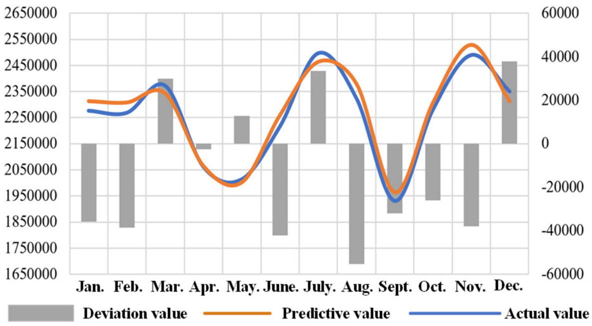


**Fig. 2.** Architecture of a typical wireless sensor node.

From Fig.2, it can be seen that the adjusted electricity consumption forecast by the seller has been slightly optimized compared to the conservative seller's electricity consumption forecast. Taking December as an example, the adjusted electricity consumption prediction error for December is 4 MWh. Therefore, the actual electricity price is 0.889 yuan/kWh, which is 0.19 yuan/kWh lower than the conservative seller's real-time electricity price. Calculating the additional costs for each month and the proportion of additional costs to total costs, it was found that even in the adjusted electricity forecast, the additional costs in December were still relatively high, but the proportion of additional costs significantly reduced, from 7.4% to 3.1%. The above data indicates that the accuracy of electricity sales forecasts improved and additional costs decreased.

**Radical electricity retailers.**

This type of electricity seller has a more aggressive power forecasting strategy than the average electricity seller, and will adjust the power forecast for the next month to a greater extent based on the power movement of the previous year and the previous month. The trend in electricity sales forecasts for the year is shown in Fig.3.

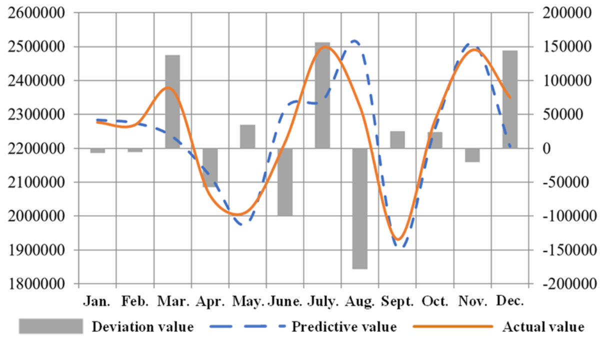


**Fig. 3.** Forecast electricity consumption trend by radical electricity retailers

From Fig.3, it can be seen that the aggressive electricity retailers did not improve their predicted electricity consumption, but instead deviated more. Taking December as an example, if the electricity consumption deviation was 144 megawatts, the real-time electricity price would be 1.42 yuan/kWh, which is higher than the real-time electricity prices of the other two electricity retailers. These data results indicate that aggressive electricity retailers‘ electricity forecasting strategies cannot improve prediction accuracy.

## 5 Conclusion

Comparing the profit situation of electricity retailers under three characteristics, it was found that the electricity prediction strategies of conservative and aggressive electricity retailers are both poor. Only the electricity prediction strategies of general electricity retailers are better, which can improve prediction accuracy, reduce additional costs, and increase profits. When predicting electricity consumption in medium to long-term contracts, electricity retailers should make minor adjustments based on the actual electricity consumption of the previous month, based on the original predicted electricity consumption. This electricity consumption prediction strategy is the best for profit improvement.

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