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Research on Outsourcing Electricity Model of Provincial Power Grid

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Abstract: With the rapid economic and social development of Province A, the province's electricity consumption level has improved significantly. During the summer and winter peak hours, the province has adopted various levels of orderly electricity use measures, and the power supply support capacity has reached the limit. Hunan's energy endowment is insufficient, and the province's power supply and demand has been unable to achieve self-balance. With the commissioning of the UHV DC project, the scale of purchasing electricity outside the province has grown rapidly. The role of foreign calls in ensuring the power supply of the province, reducing the price of electricity in the province, and improving the ecological environment are becoming more and more obvious. In order to solve the above problems, we first analyze the inter-provincial power trading varieties and the factors affecting the purchase of electricity, and analyze the problems according to the purchase situation of the province in 2018, and put forward the problems to be solved. Then, the outsourcing electricity model is established. Finally, the average electricity price of the province is analyzed by various uncertain scenarios. Under the premise of satisfying the constraints, the optimal power purchase plan is obtained, which is formulated for the province A. Provide a reference for annual and monthly trading plans.
Keywords: Outsourcing Eletricity Model, Monthly Trading Plans, Clean Energy Consumption, Smart Grid

I. INTRODUCTION

In recent years, with the rapid economic and social development of the province A, the province's electricity consumption has grown rapidly. In 2018, the total electricity consumption of the province was 174.52 billion kWh, an increase of 10.4% year-on-year. The maximum load of the province's power grid exceeded 30 million kilowatts for the first time, reaching 30.08 million kilowatts, an increase of 13.2%. During the summer and winter peak hours, the province has adopted various levels of orderly electricity use measures, and the power supply support capacity has reached the limit [1].

In A province, energy endowment is insufficient, coal is lacking oil and gas, and more than 80% of thermal coal used in the province is imported by other provinces, which is not conducive to the development of thermal power; hydropower resources have been developed more than 98%, and the general regulation performance is poor, and the output of dry season is insufficient. Half of the electricity supply and demand in the province has been unable to achieve self-balance.

With the commissioning of the UHV DC project, the scale of purchasing electricity outside the province has grown rapidly. The more external calls are used to protect the power supply of the province, reduce the price of electricity in the province, improve the ecological environment, and solve the problem of abandoning the wind in the northwest [2]. The more obvious it is. With the construction of Yazhong DC and regional ring network, the scale of outsourcing power in A province will continue to expand, and the impact on the operation and market operation of A province will be more profound.

However, due to the lack of accurate understanding of the purchase of electricity, the current purchase of electricity and electricity transactions in the province is mainly to solve the problem of lack of resources, and the role of resource allocation is not enough, resulting in insufficient utilization of power resources [3]. For example, the annual average utilization rate of Shaosha DC is below 50%.

We believe that there are many reasons for this problem. Among them, the in-depth and inaccurate understanding of the impact mechanism of foreign purchase transactions is an important reason. In response to this problem, the second section of we first analyzes the inter-provincial transaction varieties and influencing factors, and then analyzes the problem according to the purchase situation of the province in 2018, and finally puts forward the problems to be solved. The third section establishes the outsourcing electricity model, and analyzes the unit purchase cost of province A by various uncertain scenarios. Under the premise of satisfying each constraint condition, the optimal power purchase plan is adopted to reduce the outsourcing. The cost of electricity provides a reference for the province to develop annual and monthly trading plans.

II. STATUS OF OUTSOURCING ELECTRICITY IN PROVINCE A

A. Inter-provincial power trading variet

Here is no uniform standard for the division of inter-provincial power trading varieties. In December 2012, the "Regulations on Inter-provincial Energy Trading (Trial)" promulgated by the former State Electricity Regulatory Commission did not define the types of inter-provincial power trading. In 2016, the National Development and Reform Commission and the National Energy Administration formulated the "Basic Rules for Medium- and Long-Term Electricity Trading (Provisional)", which clarified that inter-provincial transactions include inter-provincial direct electricity transactions and network-to-network (regional power grids and provincial networks) transactions. In 2017, the Guangzhou Electric Power Trading Center issued the "Southern Region Inter-Regional Inter-provincial Monthly Electricity Trading Rules (Trial)", which proposed four types of monthly agreement plans, monthly power generation contract transfer, monthly concentrated bidding, and monthly surplus power incremental listing transactions. It can be considered as a supplement and improvement to the inter-provincial medium- and long-term trading varieties stipulated by the state. In 2018, the Beijing Electric Power Proposal Center issued the "Basic Rules for Medium- and Long-Term Electricity Trading (Provisional)", which divides inter-provincial medium- and long-term transactions into inter-provincial direct electricity transactions, inter-provincial delivery transactions, and inter-provincial contract transactions[4]. Considering the actual situation of the current inter-provincial transactions, the classification of the transaction types of inter-provincial power transactions is shown in Figure 1.

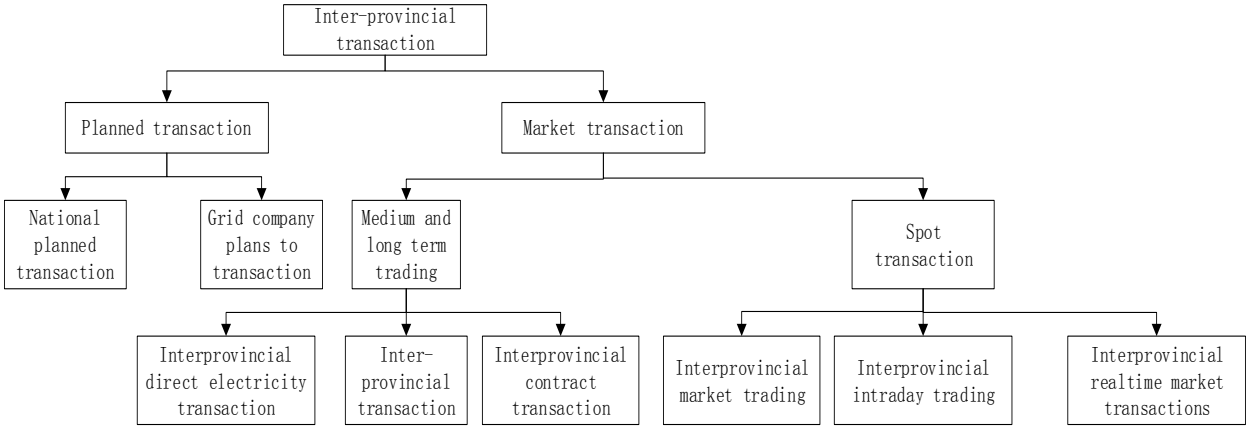

Figure 1 Cross-regional cross-provincial trading varieties

First, according to the trading mechanism, at present, China's inter-provincial transactions can be divided into two types: planned transactions and market transactions. Planned transactions mean that the trading power and price are determined in advance by the government. Market transactions refer to the trading power or price determined by the market entity in a competitive manner. With the reform of the power market, the proportion of market-oriented transactions in China is increasing. In 2018, the market-oriented transaction volume reached 32.5%.

There are two types of planned transactions in the actual implementation: one is the national planned transaction, which mainly refers to the transaction of the country to determine the on-grid price and electricity distribution plan, such as the trading of the Three Gorges and Gezhouba power to East China and South China and the provinces of Central China; The two major power grid companies use UHV grid transmission channels to serve clean energy consumption and resource optimization, and arrange inter-regional and inter-provincial electricity transactions. There are two types of inter-provincial electricity market transactions: one is medium- and long-term market transactions, mainly the electricity consumption between the provincial power grid enterprises with the main purpose of the adjustment and the market competition, and the other is the spot period transaction, mainly refers to Transactions between the provincial power grid enterprises or between power generation enterprises and provincial power grid enterprises to solve the problem of lack of electricity or potential water abandonment, wind abandonment and light abandonment in a market competition manner.

B. Factors affecting electricity purchase

1) Electricity price policy

Electricity price reform is the core of power system reform, and plays an important role in market-oriented reforms, directly affecting the cost of purchased electricity[5]. "Several Opinions of the Central Committee of the Communist Party of China and the State Council on Further Deepening the Reform of the Electric Power System" proposed to divide electricity prices into on-grid tariffs, transmission tariffs, distribution

tariffs, and terminal sales tariffs. The on-grid price has the capacity electricity price set by the state and the electricity price generated by the market bidding. The transmission and distribution price has the government pricing principle. The sales price is based on the above-mentioned electricity price, and establishes a mechanism for linkage with the on-grid price. The government regulates and supervises the price of each link according to the efficiency principle, the incentive mechanism and the requirement of attracting investment, and considering the social affordability.

The electricity price of electricity users consists of three parts, including the "reference price + floating mechanism" price negotiated with the power generation company, the government's clear transmission and distribution price (including loss) and government funds and surcharges. Among them, the agreed benchmark electricity price is negotiated and confirmed by the two parties; the agreed floating mechanism is determined by the tradable parties to comprehensively consider various market influencing factors, and negotiate the floating reference standard, floating period and floating ratio.

2) Clean energy policy

In recent years, with the rapid development of clean energy such as wind power and photovoltaics, the problem of clean energy consumption has become more and more prominent[6]. The main purpose of inter-provincial transactions is to promote the promotion of clean energy consumption. Judging from a series of policies promulgated by the state, the state attaches great importance to the issue of clean energy consumption, especially the "Notice on Establishing and Improving the Safeguard Mechanism for Renewable Energy Power Consumption" (hereinafter referred to as the Notice).

Based on the Renewable Energy Law, the Notice proposes to establish and improve a renewable energy power consumption guarantee mechanism. The core is to determine the proportion of renewable energy in each province-level region in power consumption, namely "renewable energy power consumption responsibility weight", as shown in Table 1. Each market entity completes the consumption by actually eliminating the renewable energy, purchasing the excess consumption of other market entities, and voluntarily subscribing to the green power certificate. Complete clean energy consumption indicators when arranging outsourced electricity plans.

Table 1 Responsible weight of renewable energy power consumption in all provinces

Province (District, City) 2018	Province (District, City) 2018	Province (District, City) 2018	Province (District, City) 2018	Province (District, City) 2018	Province (District, City) 2018	Province (District, City) 2018
Gansu	44.00%	48.40%	44.00%	48.40%	47.00%	51.10%
Xinjiang	21.00%	23.10%	21.00%	23.10%	22.50%	24.5
Ningxia	20.00%	22.20%	20.00%	22.00%	22.00%	24.20%
Qinghai	70.00%	77.00%	69.50%	76.50%	70.00%	77.00%
Shaanxi	17.50%	19.20%	18.50%	20.40%	21.50%	23.70%
Jiangxi	23.00%	25.10%	25.50%	28.10%	29.00%	32.10%
Henan	13.50%	14.90%	13.50%	14.90%	16.00%	17.60%
Hubei	39.00%	43.00%	37.50%	41.30%	40.00%	44.00%
Inner Mongolia	18.50%	20.40%	18.50%	20.40%	18.50%	20.40%
Sichuan	80.00%	88.00%	80.00%	88.00%	80.00%	88.00%
Hunan	46.00%	50.50%	47.00%	51.70%	49.00%	53.90%

C. Analysis of the current situation of province A

1) Power balance analysis

By the end of 2018, the power supply of the province's power grid was 45.538 million kilowatts (as shown in Figure 2), of which hydropower was 17.296 million kilowatts, accounting for 37.6%; thermal power was 21.537 million kilowatts, accounting for 46.9%; new energy was 7.10 million kilowatts, accounting for 15.5 percent. %. Among them, the proportion of hydropower installed capacity is more than double the national average, and 80% does not have the ability to peak the peak, resulting in the utilization of thermal power is less than 900 hours per year than the national average. Once it meets the dry year or even the wet years In the water season, even if the thermal power unit is fully launched, there may be some time periods and partial geographical cuts, which will bring difficulties to the power balance work.

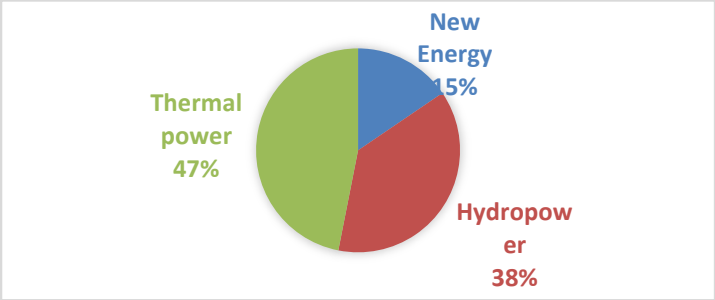

Figure II A province power grid power installation structure

In recent years, the total electricity consumption in the province of A province has maintained rapid growth, and the gap between supply and demand is on the rise. It can be seen from Fig. 3 that the power generation in province A is greater than the electricity consumption, showing two peaks in summer and winter. The second quarter is the season with the lowest electricity consumption in province A, and the power generation is relatively rich. It is predicted that in 2020 and 2025, the maximum load of A province's power grid will be about 35 million kilowatts and 48 million kilowatts respectively; in 2020, the power grid gap of A province will reach more than 5.8 million kilowatts, and by 2025, the power shortage in province A will be expanded to 8.5 million.

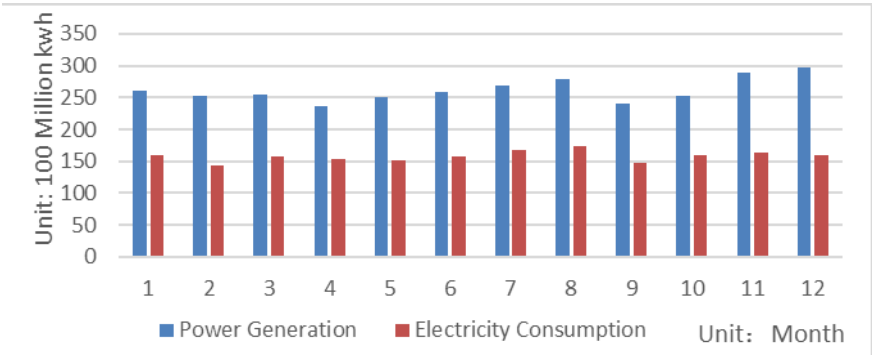

Figure 3 Electricity consumption and power generation in province A in 2018

2) Purchased electricity trading analysis

From 2015 to 2018, the scale of outsourcing power in the province A has increased rapidly (see Figure 4), and the growth rate has increased year by year. The main reasons for the growth of purchased electricity: First, the reform of transmission and distribution prices and meteorological factors, boosting the rapid growth of commercial and residential electricity consumption in the province, and promoting the growth of social electricity consumption. The second is the operation of the UHV DC, which will transport the clean energy in the northwest to the province A, laying the foundation for the scale of the purchased electricity.

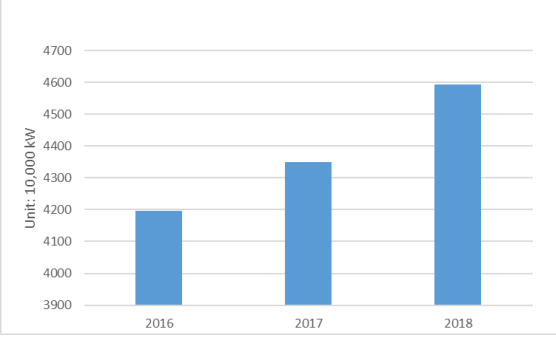

Figure 4 Changes in outsourcing power in A province from 2015 to 2018

It can be seen from Figure 5 that the electricity purchased in the province A is characterized by summer high and winter high, which is consistent with the summer and winter electricity shortage in the province A. In addition, the second quarter of the purchase of electricity is the least, which is related to the flood season in the province A.

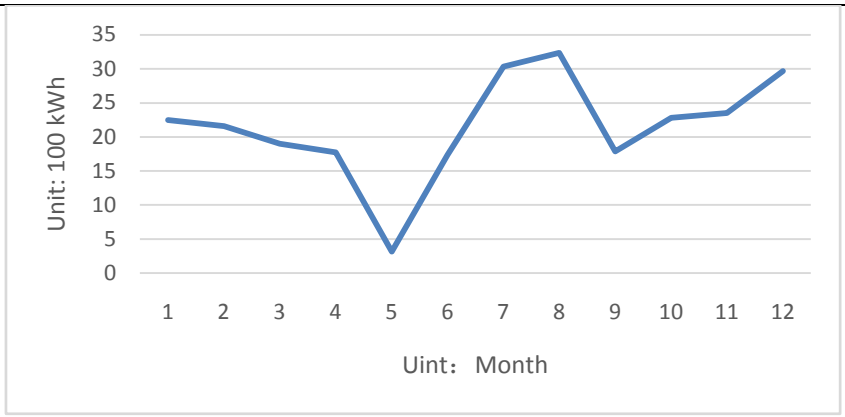

Figure 5 A province in 2018 purchased power situation

As can be seen from Figure 6, the provinces currently purchasing out of provinces are Gansu, Xinjiang, Ningxia, Qinghai, Shaanxi, Sichuan, Shanxi, and Chongqing. The competitors are Henan, Jiangxi, and Hubei. Among them, the main foreign purchase targets are Gansu and Xinjiang. The calls from outside the province are mainly from the Gansu clean energy power generation and the Three Gorges and Gezhouba hydropower transported by the Hubei-Xiang line. Among them, the maximum power supply capacity of the DC is 4.5 million kilowatts, and the three Exiang lines are 2.7 million kilowatts. According to the grid security requirements, the maximum power supply capacity of the two is about 6 million kilowatts, and it bears nearly 20% of the load in the province.

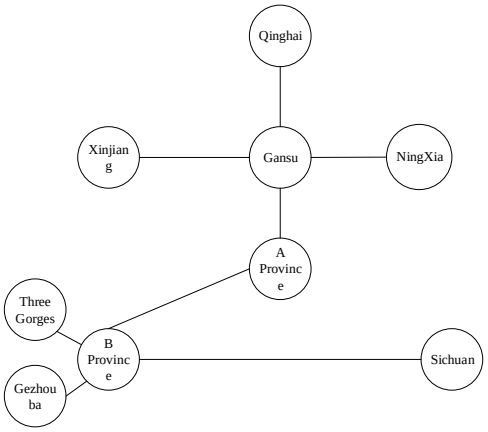

Figure 6 A province's outsourcing transactions

D. Problems to be solved

Through the analysis of the current status of purchasing electricity costs, it is necessary to solve the following problems to control the cost of purchasing electricity:

Question 1: Determine the optimal annual outsourcing power plan. Through the study of purchased objects, the scale of outsourcing electricity in A province is determined, which provides a scientific basis for the decision-making and preparation of the annual plan.

Question 2: The optimal arrangement for the monthly electricity plan. Under the conditions determined by the annual electricity plan, we will study the rational distribution and arrangement of various types of electricity in each month, not only to meet the full consumption of renewable energy such as hydropower, but also to ensure that the purchase of electricity meets the needs of users.

III. OUTSOURCED ELECTRICITY MODEL

a. Model establishment

The annual electricity plan of each province is formulated by the relevant government departments, but the provincial power companies can realize the purchase of electricity through the reasonable arrangement of

monthly electricity and the government's annual electricity plan, power balance and priority of water and electricity. The average price is the smallest. This model aims to study the problem of outsourced electricity under the premise of hydropower priority in the province. Therefore, clean energy consumption is also the goal of we. When the model is established, this goal is transformed into a constraint condition.

i. Objective function

The proportion of hydropower installed in province A is high, and the constraints on power purchase optimization in the grid water and electricity season are different. Therefore, the optimization of power purchase is more reasonable on a monthly basis. In this section, thermal power and new energy are used as independent variables. The electricity demand and hydropower on-grid electricity in the province are taken as parameters, and the power balance is used as the constraint. The minimum purchase price of the province is used as the objective function to establish the purchase of the province. The electric cost optimization model is solved by solving the optimal monthly electricity plan.

Assume that province A can purchase M homes for thermal power plants, N for new energy power plants, and V homes for hydropower plants. The electricity purchased from the i-th power plant in the month of j is $Q_{i,j}^{a_k}$(k=1,2,3), corresponding to the purchase price is $P_{i,j}^{a_k}$。Among them, a_1 represents thermal power, a_2 represents hydropower, and a_3 represents new energy.

The average price of electricity purchase reflects the cost of electricity purchase. The lower the average price of electricity purchase, the lower the procurement cost of province A, and the more it can increase its own economic benefits. Therefore, we chooses to use the minimum purchase price as the objective function.

$$\text{Min} = \frac{\Sigma_{i=1}^{M} Q_{i,j}^{a1} + \Sigma_{i=1}^{N} Q_{i,j}^{a2} + \Sigma_{i=1}^{V} Q_{i,j}^{a3}}{Q} \tag{1}$$

ii. Restrictions

Step 1 : Monthly electricity balance constraint. The lack of electricity will bring about very large social losses and economic losses. Therefore, the electricity purchase plan must first meet the demand for electricity in the province. Even if the electricity is relatively expensive, it must be purchased if it is needed. That is to say, as the basis of safe and reliable power supply of the power grid, the power balance is an important constraint for the company to make a monthly power purchase plan. The power company must consider the provincial power balance to consider the power purchase cost of the provincial power company.

The power balance constraint condition, that is, the purchase of electricity meets the monthly electricity consumption and load demand in the province. Specifically, the monthly electricity consumption in the province, the electricity generated in the province, and the electricity purchased from the province during the month should be equal to the estimated electricity demand in the province and the planned monthly sales to the province. The sum of the electricity. Let the estimated demand in the province for j month be S_j, monthly power generation is T_j, monthly delivery power is Wj, the average loss rate is δ. The power coordination constraint of the j month can be expressed as:

$$(1-\delta)\left(\sum_{i=1}^{M} Q_{i,j}^{a_1} + \sum_{i=1}^{N} Q_{i,j}^{a_2} + \sum_{i=1}^{V} Q_{i,j}^{a_3}\right) = S_j + T_j + W_j \tag{2}$$

Step 2 : The annual demand for electricity demand is constrained. The sum of the estimated electricity demand in each month of the province is equal to the total electricity demand estimated by the province in that year. That is :

$$\sum_{j=1}^{12} S_j = q_{\text{need}}\,(1 + t_{\text{need}}) \tag{3}$$

Step 3 : Clean Energy Annual Plan Constraints. The sum of clean energy sources expected to be purchased in the province is not lower than the clean energy consumption index. Let A province's clean energy consumption index be r.

$$\frac{\Sigma_{i=1}^{N} Q_{i,j}^{a2} + \Sigma_{i=1}^{V} Q_{i,j}^{a3}}{\Sigma_{i=1}^{M} Q_{i,j}^{a1} + \Sigma_{i=1}^{N} Q_{i,j}^{a2} + \Sigma_{i=1}^{V} Q_{i,j}^{a3}} \geq r \tag{4}$$

b. Case analysis

i. Scenario classification

The outsourced electricity model refers to how the provincial grid companies adopt optimal decisions when there is uncertainty, so that the cost of purchasing electricity per kWh is the lowest under the premise of satisfying various constraints. Therefore, we classifies hydropower uncertainty scenarios, as shown in Table 2, to facilitate analysis. When different scenarios occur, how does A province formulate a power purchase strategy in a timely manner, so that the cost of electricity purchase per kilowatt is the smallest. It should be noted that in all the following scenario analysis, the data used are based on 2018 data. On this basis, the parameters are set by

increasing the amplitude, and the problem is solved by MATLAB software. The optimal power arrangement and the minimum purchase price are averaged, and the results are analyzed.

Table2 Purchase scenario classification

Scene 1	Scene 2	Scene 3
Normal incoming water +0%	More than +15% of incoming water	Less than -15% of incoming water

ii. Simulation calculation

For the characteristics of the provincial power grid, the specific content of the optimization includes the following aspects.

①To meet the market demand for electricity, to achieve power balance;

②All hydropower in the province;

③Optimized distribution of purchased electricity in the whole year;

④Complete the clean energy consumption indicator.

The specific optimization calculation results are as follows.

Scenario 1: When the water and electricity supply are both deterministic, the electricity purchase plan is strictly implemented at this time, and the average purchase price is 346.25 yuan/MWh.

Scenario 2: It is assumed that the actual demand is unchanged, but for the wet years, the water and electricity coming from the water is 15% higher than the forecast. Due to the large hydropower generation, province A needs to fully absorb multiple hydropower. Therefore, it is necessary to reduce the purchased electricity. According to the outsourcing electricity model of we, the average purchase price is 336.47 yuan/MWh.

Scenario 3: It is assumed that the actual demand is unchanged, but for the dry year, the water and electricity coming from the water is reduced by 15%. Due to the reduction in hydropower generation, province A must purchase additional electricity in order to meet its own needs. At the same time, due to other conditions, A province cannot purchase electricity at will. Through calculation, the average purchase price is 348.26 yuan / MWh.

The best purchased electricity in Province A under each scenario is shown in Table 3.

Table 3 Optimized monthly outsourced electricity

	Scene 1				Scene 2				Scene 3			
	Thermal power	hydropower	new energy	total	Thermal power	hydropower	new energy	total	Thermal power	hydropower	new energy	total
January	9.02	8.40	3.87	21.29	7.67	7.14	3.29	18.10	10.37	9.66	4.45	24.48
February	3.24	7.90	1.39	12.53	2.75	6.72	1.18	10.65	3.73	9.09	1.60	14.41
March	4.46	6.70	1.91	13.07	3.79	5.70	1.62	11.11	5.13	7.71	2.20	15.03
April	2.56	11.50	1.10	15.16	2.18	9.78	0.94	12.89	2.94	13.23	1.27	17.43
May	2.65	9.80	1.13	13.58	2.25	8.33	0.96	11.54	3.05	11.27	1.30	15.62
June	3.12	9.50	1.34	13.96	2.65	8.08	1.14	11.87	3.59	10.93	1.54	16.05
July	11.54	9.80	4.95	26.29	9.81	8.33	4.21	22.35	13.27	11.27	5.69	30.23
August	10.40	12.40	4.46	27.26	8.84	10.54	3.79	23.17	11.96	14.26	5.13	31.35
September	6.08	6.20	2.61	14.89	5.17	5.27	2.22	12.66	6.99	7.13	3.00	17.12
October	4.36	12.10	1.87	18.33	3.71	10.29	1.59	15.58	5.01	13.92	2.15	21.08
November	6.90	11.20	2.96	21.06	5.87	9.52	2.52	17.90	7.94	12.88	3.40	24.22
December	8.95	9.50	3.83	22.28	7.61	8.08	3.26	18.94	10.29	10.93	4.40	25.62

IV. CONCLUSION

In the course of business, power grid enterprises must ensure their own economic profits and meet the needs of social development. Due to the lack of resources in the province A, the electricity consumption gap has increased year by year, and the scale of purchased electricity has increased year by year. Due to the in-depth and inaccurate understanding of the impact mechanism of foreign purchases, there is a problem of low channel utilization and high cost of outsourcing electricity. In order to solve the above problems, we first analyzes the inter-provincial power trading varieties and the factors affecting the purchase of electricity, and analyzes the problems according to the purchase situation of the province in 2018, and puts forward the problems to be solved. Then, the outsourcing electricity model is established. Finally, the average electricity price of the province is analyzed by various uncertain scenarios. Under the premise of satisfying the constraints, the optimal power purchase plan is obtained, which is formulated for the province A. Provide a reference for annual and monthly trading plans.

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