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Power Network Planning Method of New Energy Consumption Based on Automatic Control Theory

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Abstract: With the shortage of resources of traditional fossil energy and the increasingly serious problems of environmental pollution, wind power generation began to develop rapidly. Therefore, how to improve the absorption capacity of new energy and reduce wind abandonment new energy. In particular, as a major energy, Xinjiang wind has broad prospects for new energy development. "Abandoning wind and limiting power" is also very serious, which restricts the development of new energy. Therefore, in order to make up for the lack of local consumption capacity of level, this paper considers building power transmission channels across regions and countries, expanding the wind power balance area and reducing wind abandonment. In the context of large-scale access of new energy to the power grid, the power grid planning research is mainly based on the consumption capacity of new energy, and this method is applied to the actual power grid research in a province of China. Based on the actual data of a region in a province, a comprehensive calculation example is designed to simulate and analyze the contribution of various innovative consumption paths to the consumption of new energy; Two groups of different data are selected for simulation to reflect the relationship between the development scale of new energy and the demand for consumption capacity under different energy structure scenarios. Through simulation analysis, the technical feasibility and economy of comprehensive consumption of new energy are verified, in order to provide reference for other regions.

1. Introduction

The use of fossil energy is increasing year by year. Energy shortage and environmental pollution have become global problems. The report of "Research on power planning" points out that the "14th five year plan" is a key period for China's energy transformation and clean energy development, reducing dependence on fossil energy, steadily promoting the development of natural clean energy such as wind, light and geothermal in the northwest and the distributed energy system in the economically developed areas in the East and central China[1].

However, the natural distribution characteristics and intermittent fluctuation characteristics of new energy such as wind and light have led to the problem of "wind abandonment" of wind farms and "light abandonment" of photovoltaic power stations, especially in Northwest China, the problem of new energy consumption is prominent. For example, Xinjiang, Gansu, Qinghai and other regions are rich in new energy resources such as wind and light, and the total reserves, installed capacity and "wind / light abandonment" rate are all in the forefront of the country. China's most abundant solar region, with annual radiation of 6680~8400mj/m2 [2]. The installed capacity of wind power in Xinjiang was close to 30million kW, and the annual wind rejection rate was 23% and the light rejection rate was 16%, both ranking first in the country [3]. Accurate evaluation of wind power consumption capacity in areas for power planning, power grid planning and other work. Therefore, the evaluation is the basis of studying how to improve wind power consumption. According to the objective of evaluating the renewable energy consumption capacity, the existing research power grid can be roughly divided into two stages [4]. The first stage is mainly from the planning level, using the maximum installed capacity of renewable energy to characterize. The main purpose is to evaluate the consumption level of renewable energy in the second stage of renewable energy power station planning from multiple time scales, such as medium and long-term, short-term, ultra short-term and so on. Compared with the first stage, the consideration of operation is increased [5]. At present, there are two main methods to determine the capacity: one is to calculate the maximum allowable system without considering the new energy output limit; The second method goal, and discards some new energy output when the system peak shaving margin is insufficient, and its calculation results are system. At present, the first method is too idealistic and less applied, and the research tends to abandon the output of new energy to optimize the consumption of new energy [6].

Starting from the actual situation of the power grid in province a, this paper focuses on the analysis of the new energy consumption of the power grid in province a in the past two years, taking last year as the base year. This paper adheres to the principle of safe and stable operation of power grid, focuses on the admissibility of 220kV power grid, and further obtains the actual capacity of new energy in the region by analyzing the key factors affecting the regional capacity, and puts forward relevant suggestions for the next step through the integration of automatic control theory.

2. Theoretical Research on Power Grid Planning Method for New Energy Consumption

2.1. Wind Abandonment

Resulting in wind abandonment. The difference between the maximum capacity of network supply and the minimum technical output is the peak shaving margin of the system. Taking wind power as a negative load, the generalized power load curve is obtained. Due to the volatility and uncontrollability of wind power, the peak valley difference of generalized power load increases, and the peak shaving demand increases, Limited by the minimum technical output and start-up and shutdown time of conventional units, the output cannot be reduced during the low load period, resulting in the rejection of air, and the calculated rejection air volume is much larger than the normal rejection air volume [7]. The wind power load matching degree is used to judge the generation tracking load characteristics of the interconnected area, and the source load space-time matching measurement is carried out for the interconnected area [8]. In this paper, the product of wind power load matching degree and maximum rejection air volume is used to represent the corrected rejection air. The corrected waste air volume is used as the technical basis for the interconnection area. There is space-time complementarity between the wind power rich area and the surrounding regional power grid. After the power grid interconnection, the size of the waste air volume is compared. The smaller the waste air volume, the higher the feasibility of power grid interconnection [9-10].

2.2. Main Factors of Wind Abandonment

The main factors affecting the consumption of wind power include the influence of wind power itself and the influence of power grid.

(1) Wind power characteristics

The influencing factors of wind power itself mainly include the prediction accuracy of wind power and the uncontrollable novelty of wind power itself. Accurate measurement of wind power output is conducive to the dispatching operation of the power grid and can effectively reduce wind abandonment. The randomness will affect the stability and economy. When the wind power is in peak valley and the load is in low valley, it will cause the reverse peak regulation of the system.However, due to the technical limitation of the minimum start and stop of the conventional units, the output cannot be reduced when the load is low, and the wind abandonment of the wind farm will increase significantly [11]. When the load is at the peak and valley and the wind power is at the trough, the system reserve is insufficient and peak regulation is difficult[12].

(2) Grid Impact

Power grid factors are mainly studied from three aspects: source network load, mainly including unreasonable power structure, insufficient transmission capacity and load characteristics [13].

The structure of the transmission network will affect the transmission, thus affecting the consumption capacity of new energy. In addition, wind power in many regions is far away from the load center and requires long-distance transmission. In the transmission process, due to the limitation, some electric energy will often be lost [14]. Therefore, the transmission capacity of the line and the topology of the transmission line will affect the consumption of new energy [15].

The power supply and demand always protect the dynamic balance, so the power generation in the grid will change with the change of load. With the economic growth, the load continues to grow, which will increase the consumption of new energy, but the load growth increases the margin, making it more difficult for the system to peak shaving [16]. At present, China's power supply is still dominated by thermal power, which is limited by the planning and operation technology of new energy units, resulting in excess power of the power supply and aggravating the problem of wind abandonment. Therefore, the standby rate of the system and the minimum technical output coefficient of conventional units will have an impact on the wind abandonment of wind farms [17-18].

Based on the above analysis, the effective ways to solve the problem of wind curtailment are to increase the construction of peak shaving power supply, enhance the power transmission capacity and adjust the wind power consumption policy. Based on the current situation that Xinjiang's local consumption capacity is insufficient and the development of UHV transmission lines is relatively successful, this paper puts forward a method of using tie lines to send excess wind power out to achieve the balance of wind power among regions. The grid connection of new energy in each region is measured according to the volume of waste air.

3. Example Design of Power Grid Planning for New Energy Consumption

3.1. Related Formula

Equality constraints:

$$P_{Gi} - P_{Li} - U_i \sum_{j=1}^{j=n} U_j (G_{ij} \cos\delta_{ij} + B_{ij} \sin\delta_{ij}) = 0 \tag{1}$$

$$Q_{Gi} - Q_{Li} - U_i \sum_{j=1}^{j=n} U_j (G_{ij} \sin\delta_{ij} - B_{ij} \cos\delta_{ij}) = 0 \tag{2}$$

P. Q is the load carried by node i, and u is the voltage amplitude of node i; N is the number of nodes in the network.

Inequality constraint:

$$P_k \le P_k^{\max} \quad k \in \Omega_{line} \tag{3}$$

Where PK is the active power value of line k, and pkmax is the maximum allowable active power value of the line; Line is a collection of network lines.

$$U_i^{\min} \le U_i \le U_i^{\max} \quad i \in \Omega_{node} \tag{4}$$

Where UI is the voltage of node i; Uimax and uimin are the upper and lower voltage limits of node i respectively; Node is a collection of network nodes.

3.2. Economic Analysis of Hydrogen Energy Storage Standard Example

The application of hydrogen energy in power system is mainly divided into "hydrogen energy storage" and "electric hydrogen production". Among them, the "hydrogen energy storage" category includes four subsystems: electrolytic water hydrogen production, high-pressure hydrogen storage, fuel cell / gas turbine hydrogen power generation and hydrogen injection, while the other category only includes two subsystems: electrolytic water hydrogen production and hydrogen injection. "Hydrogen production by electricity" consists of two links: hydrogen production by electrolytic water and hydrogen injection.

It is estimated that under the output of 10000nm3/h, the equivalent hydrogen production time is 8 hours per day, the equivalent power generation time of fuel cell is 16 hours per day, the rated power of electrolyzer is 45000 kW, the rated power of fuel cell is 8900 kW, the investment cost is 417 million yuan, and the internal rate of return is less than 0.5%, which is not feasible for investment. After calculation, the electricity price for hydrogen production is -0.27 yuan / kWh, which can ensure an internal rate of return of 6% for hydrogen energy storage.

The boundary condition for the economic calculation of the hydrogen energy storage system, which only includes the hydrogen generation and injection subsystem. The main role of hydrogen energy storage is to produce hydrogen by electricity to absorb new energy, rather than as a power source to supplement electricity. It is estimated that under the output of 10000nm3/h, the equivalent hydrogen production time is 8 hours per day, the rated power of the electrolytic cell needs to be configured is 45000 kW, the investment cost is 315 million yuan, the hydrogen sales price is 20 yuan /kg, and the internal rate of return is less than 0.5%, which is not feasible for investment. After calculation, the electricity price for hydrogen production is 0.028 yuan / kWh, which can ensure an internal rate of return of 6% for hydrogen energy storage.

Table 1. Optimize operation boundary conditions

	Upper limit	Remarks
Maximum outgoing power	5000MW	
Maximum input power	5000MW	
Capacity of thermal motor assembly machine	6237MW	40% deep peak shaving
Light rejection	5%	
Investment cost of electric hydrogen storage	7000 yuan /kw	
Electric hydrogen storage charging subsidy price	0 yuan	Ancillary services
Price of hydrogen produced by electricity for energy storage	20 yuan /kg	
Life cycle of electric hydrogen production	10 years	

After adding hydrogen energy storage, the light rejection rate of photovoltaic can be controlled within 5%, and when the installed capacity of photovoltaic reaches 12429mw, the planned rated power of hydrogen energy storage is 1450mw, accounting for 11.6% of the installed capacity of photovoltaic, which is the same as electrochemical energy storage. The daily energy consumption of 7421 MWh is greater than the daily energy consumption of electrochemical energy storage.

4. Example Analysis of Power Grid Planning for New Energy Consumption

4.1. Electricity Delivery and Deep Peak Shaving to Absorb New Energy

The installed capacity of thermal power units participating in peak shaving in area a during the 13th five year plan and the 14th five year plan is shown in Table 2. The capacity of new peak shaving units in 2024 will be increased on the existing basis according to the scale of new energy development.

Table 2. Capacity of a economizer motor assembly in 2020 and 2025

	2020	2025
Installed capacity of peak shaving unit	1858	2239
Deep peak shaving limit	475	756

According to the long-term plan of the power grid in region a, the power exchange limit will be 1350mw by 2025 (at a growth rate of 5%). Figure 1 shows the increase of export power of province a in 2025.

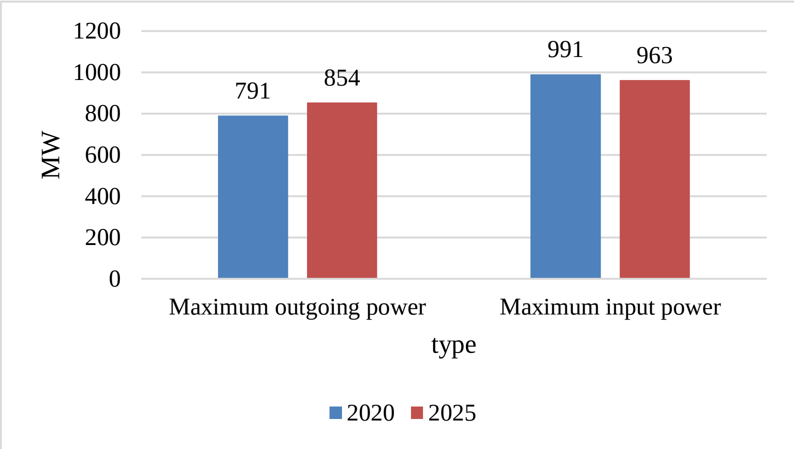

Figure 1. Export power of province a in 2020 and 2025

4.2. Assessment of Absorption Capacity through Delivery and Peak Shaving

In 2024, a province is expected to add another 2200mw of photovoltaic installed capacity, with an installed capacity of 3096mw. After adding electric loads through electric heating, electric hydrogen production, electric start-up, etc., the difference between the typical daily load of a province and the output of water and thermal power operation, and the photovoltaic output curve are shown in Figure 2. It can be seen from Figure 2 that in December 2025, the power supply is insufficient, and power needs to be injected from the main network of other provinces. The reason is that a province produces a large amount of synthetic ammonia and petroleum and petrochemicals every year, which consumes a large amount of electric energy. Therefore, the installed capacity of photovoltaic can be further increased in a province.

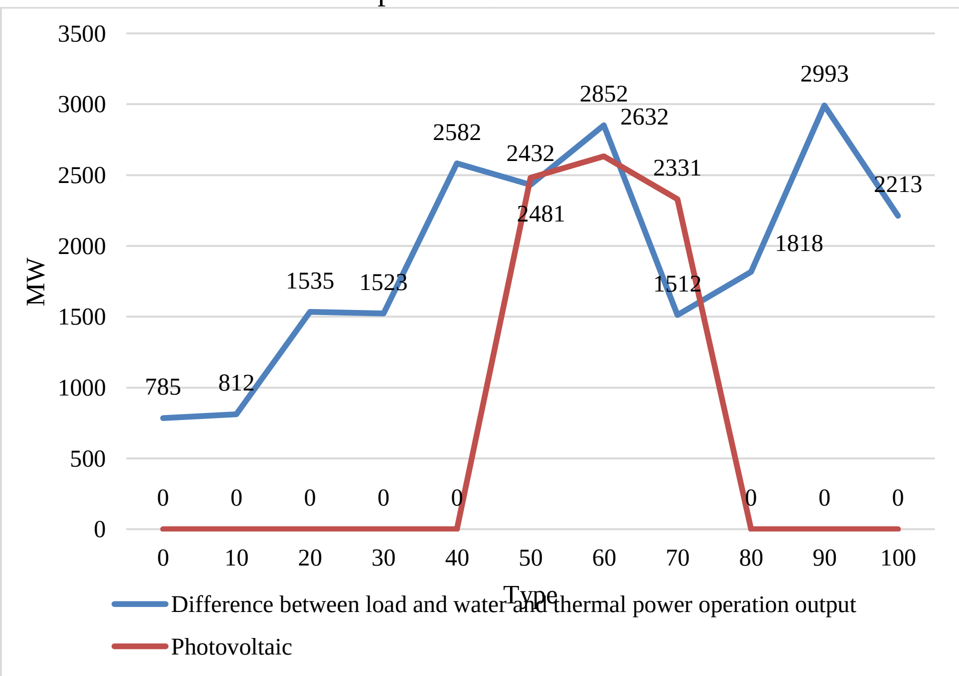

Figure 2. On a typical day in 2025, the difference between load and water and thermal power operation output and photovoltaic output curve

4.3. Scenario 2 Energy Storage Promotes New Energy Consumption

The installed capacity of thermal power units participating in peak shaving in area B during the 13th and 14th five year plan periods is shown in Table 3. The capacity of new peak shaving units in 2025 will be increased on the existing basis according to the scale of new energy development. According to the long-term plan of power grid B, the power exchange limit between region B and the main network of other provinces will be 700MW by 2024 (at a growth rate of 5%).

Table 3. Capacity of B economizer motor assembly in 2020 and 2025

	2020	2025
Installed capacity of peak shaving unit	188	208
Deep peak shaving limit	79.3	83.4

Different from region a, region B only has light rejection during the period of 12:30-17:30 when the photovoltaic output is large, and the power supply is insufficient in other periods. Power is injected from the main network of other provinces. Therefore, thermal power peak shaving, outward transmission or energy storage are considered when photovoltaic output is large. From 12:30 to 17:30, local thermal power units are used for deep peak shaving. After calculation, after deep peak shaving of thermal power units, figure 3 shows the difference between B load and hydro thermal power operation output and photovoltaic output curve after deep peak shaving. As shown in Figure 3, the upper limit of outgoing power in area B is 260mw, and the maximum outgoing power required for photovoltaic output is 220MW. Therefore, B can absorb all photovoltaic through deep peak shaving and outgoing of thermal power units.

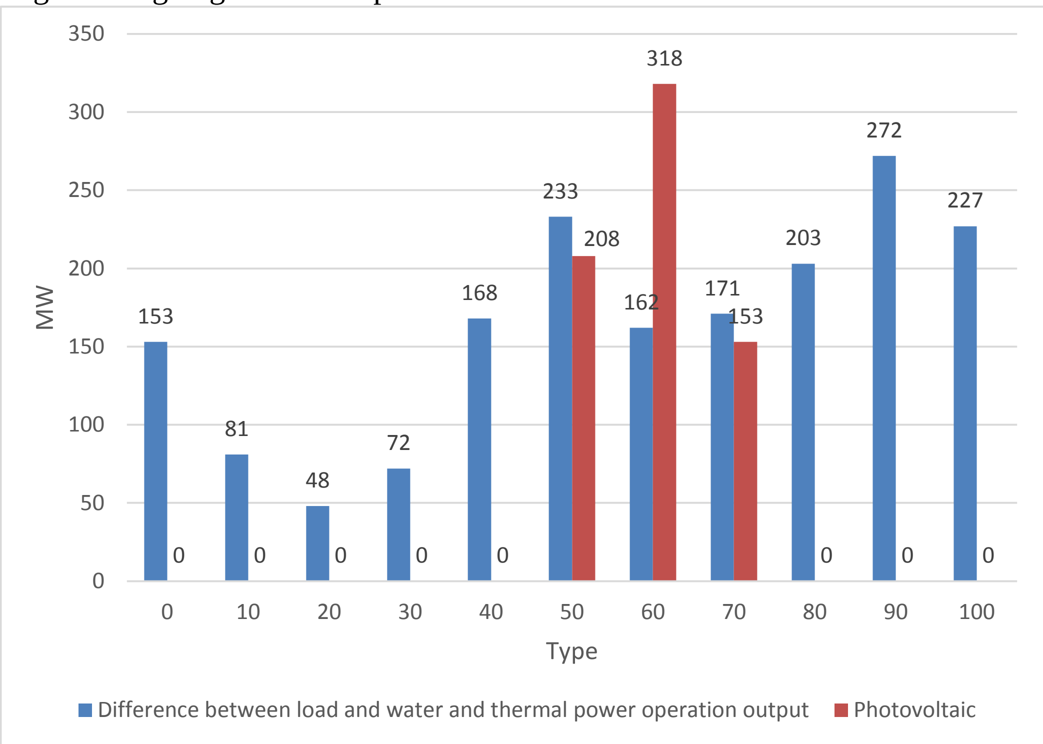

Figure 3. After deep peak shaving, the difference between load and hydro thermal power operation output and photovoltaic output curve in area B on typical days

5. Conclusion

In recent years, China has made some improvements in the diversity of energy structure, issued a number of strategic plans, made greater efforts and covered a wider range, changed the supply side structure, actively explored the path of energy conservation and emission reduction, and strive to achieve carbon peak in five years and carbon neutralization in 25 years. This instruction puts forward higher requirements for China's energy system. To sum up, the comprehensive consumption mode of new energy explored in this paper, the calculation model of consumption space potential of electric energy substitution and hydrogen energy substitution, and the optimization model of high proportion new energy power system including electrochemical / hydrogen energy storage, have great feasibility in terms of economy and effectiveness. This paper analyzes the effectiveness of the proposed methods, also evaluates the economy of energy storage and other means, and gives suggestions on the promotion of new energy electricity price when it is technically and economically feasible, so as to provide reference for other regions.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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