Research on Limitations of Energy Storage Promoting the Consumption Role of New Energy New Energy Consumption Case from China

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Abstract. The principle of energy storage promoting new energy consumption was analyzed and the role of energy storage in new energy consumption under different installed penetration rates of new energy was rearranged in this article. In addition, a detailed analysis was conducted on the limitations of daily regulated energy storage on new energy consumption with data from a major new energy province in northwest China as an example. The case results revealed that in case of a high penetration rate of new energy, there will be a gradual weakening in the improvement effect of increasing daily regulated energy storage on new energy consumption and there will be a gradual "saturation" in the utilization rate of new energy accompanied by the increase of energy storage scale. Nonetheless, measures such as the flexible transformation of thermal power and increase of external transmission channels to promote consumption are not related to the "saturation effect". The conclusion of this article can be as a reference for other countries and regions in the allocation of flexible resources for promoting new energy consumption.

Keywords: Daily regulated energy storage; New energy consumption; Saturation effect.

There is a tendency for the rapid development of new energy storage over recent years, which has formed a strong voice in the power industry. [1] Furthermore, how to position energy storage has become an important issue requiring to be addressed in the safe, economical and stable operation of the power grid and the construction of new power systems. The research team believed that in case of failure to gain a scientific understanding of the role of energy storage in promoting new energy consumption as soon as possible, there will be a higher price to pay for the development of energy storage reaching a certain stage before resolving the accumulation issues. Based on this, the research team utilized power operation simulation tools to research the limitations of daily regulated energy storage, namely the analysis of the "saturation effect" of daily regulated energy storage and the presentation of relevant suggestions.

1. New energy and energy storage development in China

1.1 Development and consumption of new energy in China

Thanks to a large scale of new energy development, China has maintained its position as the country with the largest installed capacity of new energy in the world for many consecutive years. As of the end of 2022, the installed capacity of new energy in China reached 799GW (758GW for installed capacity of wind and PV power), a year-on-year increase of 18.7%, accounting for 31.2% of the total installed capacity (2.564TW).

Multiple provinces in China have released their new energy development plans. From the perspective of the future, it is conservatively estimated that by 2030, the installed capacity of new energy power generation in China will far exceed 1.2TW, or even reach 1.7-1.8TW. New energy power generation has the characteristic of anti-peak load regulation. Therefore, significant peak

load regulation demands and consumption pressures will be inevitably triggered in the system by such a huge installed capacity of new energy. [2].

With the joint efforts of the government, power grid enterprises, power generation enterprises, users and upstream equipment enterprises over the recent years, the newly-added annual installed capacity of wind and PV power has continuously exceeded 100GW, a significant increase compared to the first four years of the "13th Five-year Plan" (with an average annual growth of about 60GW)[3]. However, the utilization rate of new energy sources in China has exceeded 95% for four consecutive years, in which the utilization rates of wind power and PV power generation in 2022 were 96.8% and 98.3% respectively, playing a dominant role in promoting low-carbon transformation in the power industry. The changes in the utilization rates of new energy in China in recent years are shown in Figure 1.

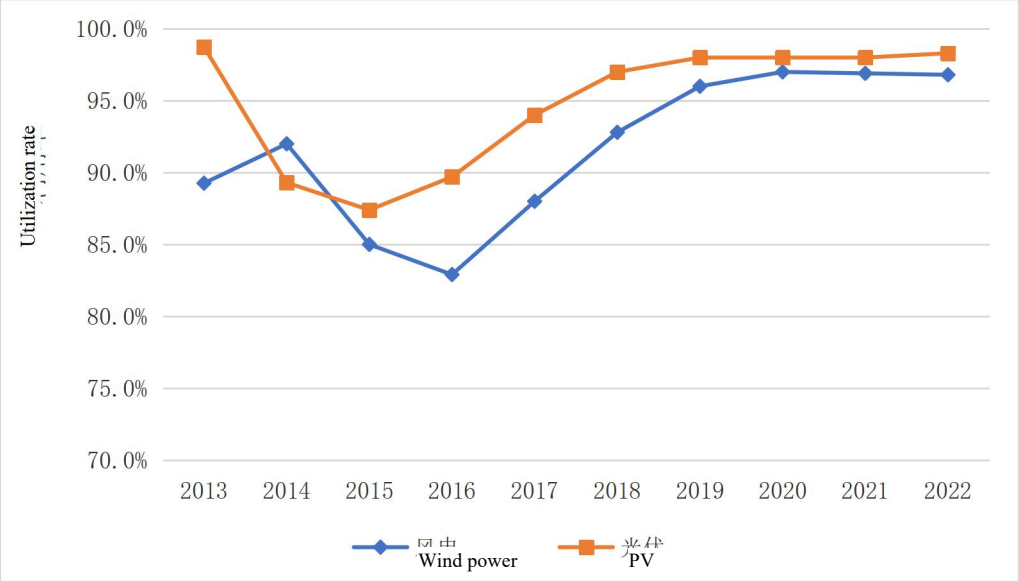

Figure 1 Changes in the Utilization Rates of New Energy in China in Recent Years

1.2 Energy storage requirements for new energy configuration

According to the *Implementation Scheme for the Development of New Energy Storage in the 14th Five-Year Plan* issued by the Chinese energy regulatory department, greater efforts will be made to develop new energy storage on the power side in the future. A focus will be put on the layout of a group of system-friendly new energy power stations for new energy storage with reasonable configuration in areas with abundant new energy resources, such as Inner Mongolia, Xinjiang, Gansu, Qinghai and other areas with a high penetration rate of new energy.

As of the end of 2022, a total of 24 provinces in China have issued new energy configuration and energy storage policies with configuration requirements mostly reflected on 10%-20% of the installed capacity of wind and PV power and configuration time mostly ranging from 2 to 3 hours [4]. Among them, there are requirements for centralized wind and PV power station configuration and energy storage from major new energy provinces in the western and northern regions of China and the requirements for distributed new energy configuration and energy storage in the middle east of China.

1.3 Assumption of energy storage promoting new energy consumption

In consideration of the booming development of new energy storage, some experts and scholars deem that energy storage can solve all the issues of new energy consumption [5]. In case of technological advancement in energy storage in the future and a significant drop in the cost, enough energy storage can be configured in the system to solve the issue of new energy consumption.

Through the research, we found that for new energy storage facilities with daily regulation and limited energy storage volume, in case of a high installed penetration rate of new energy and

continuous and long-term large outbreaks of new energy, the new energy storage can fully store energy but cannot determine the discharge period, resulting in a limited role on new energy consumption in regardless of the volume of energy storage installed. In other words, there is a saturation effect in energy storage promoting new energy consumption, which can provide a reference for more effective allocation of various types of peak load regulation resources in the future.

2. Saturation effect principle of energy storage promoting consumption

Energy storage is a passive power source and its essence in promoting new energy consumption lies in "transporting" the electric quantity of wind and PV abandonment that is difficult to use until the peak of net load from the overall point of view, reducing the output discharge of conventional power sources. Hence, the "upper capacity limit" of the daily regulated energy storage to promote consumption depends on the dischargeable energy space formed by the press-out force under conventional power sources.

2.1 Low penetration rate of new energy

When the penetration rate of new energy is low, there is no wind or PV abandonment throughout the day and the utilization rate of new energy consumption can reach 100%. When the installed proportion of new energy is less than 30%, the theoretical output of new energy is relatively small and there will be a larger consumption space formed by the difference between the original load and the minimum fixed output, achieving no power abandonment.

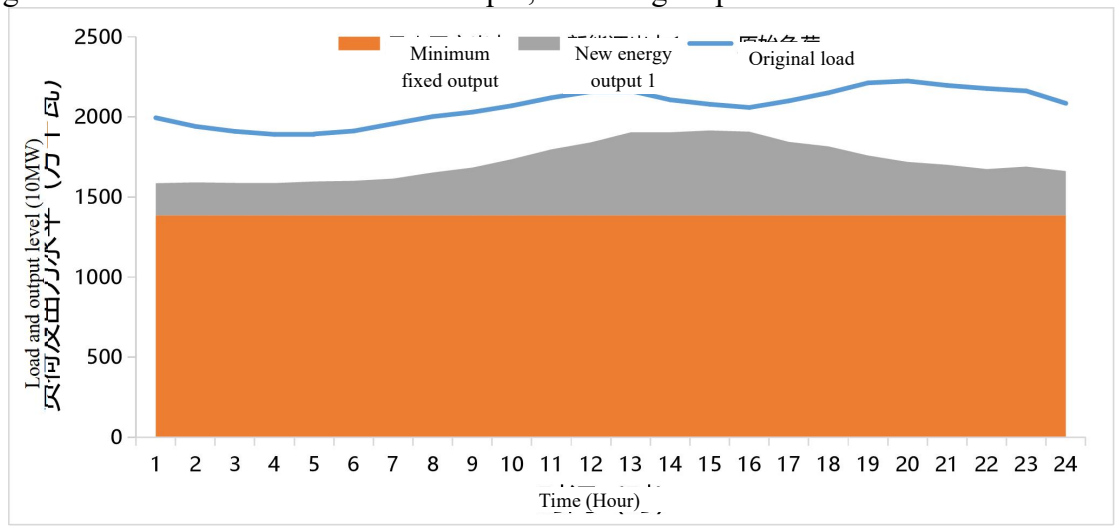

Figure 2 Schematic Diagram of New Energy Consumption (Possibility of Achieving No Energy Abandonment)

2.2 Increased penetration rate of new energy

There is wind and PV abandonment during certain periods of the day. Energy storage is charged during wind and PV abandonment and discharged during peak load periods to promote consumption. As for the research case in China, as the proportion of installed capacity of new energy further increases from 30% to 60%, the theoretical output of new energy exceeds the consumption space in some periods of the day. The flexible transformation of thermal power can reduce the minimum fixed output and directly increase the consumption space. By installing energy storage, charging is made in case of energy abandonment in new energy, and discharging is made in case of insufficient power, achieving the equivalent expansion of storage space.

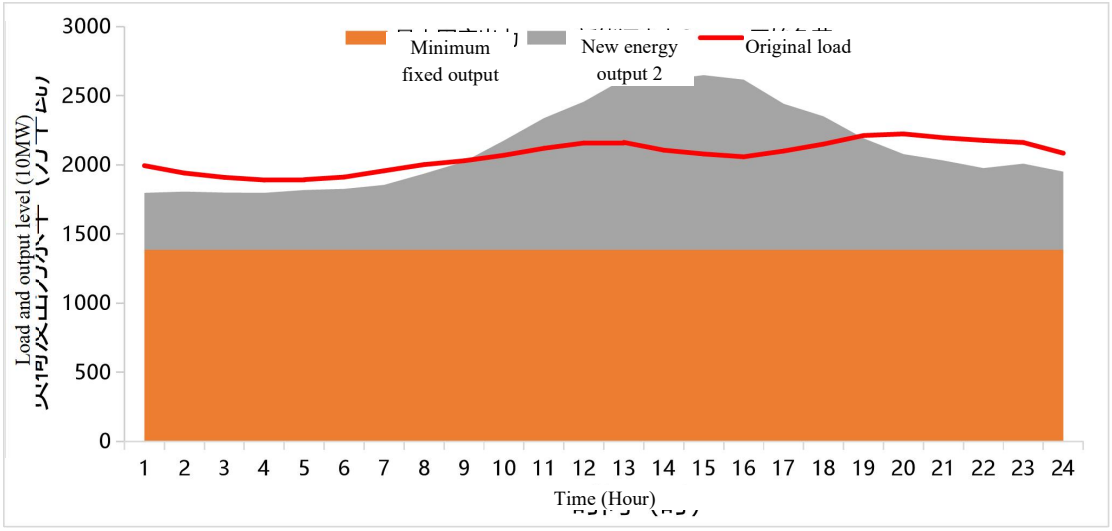

Figure 3 Energy Storage Promoting New Energy Consumption (Energy Abandonment at Some Periods)

2.3 High penetration rate of new energy

As for the research case in China, when the installed proportion of new energy exceeds 60%, the theoretical output of new energy is relatively large, far exceeding the range of consumption space. In addition, the state of wind and PV abandonment is maintained at all periods of the day. At this point, the measure of flexible transformation of thermal power can further reduce the minimum output and promote consumption. But, the daily regulated energy storage can be charged 24 hours a day with power abandonment but cannot be discharged at any period, making it difficult to continue to promote consumption.

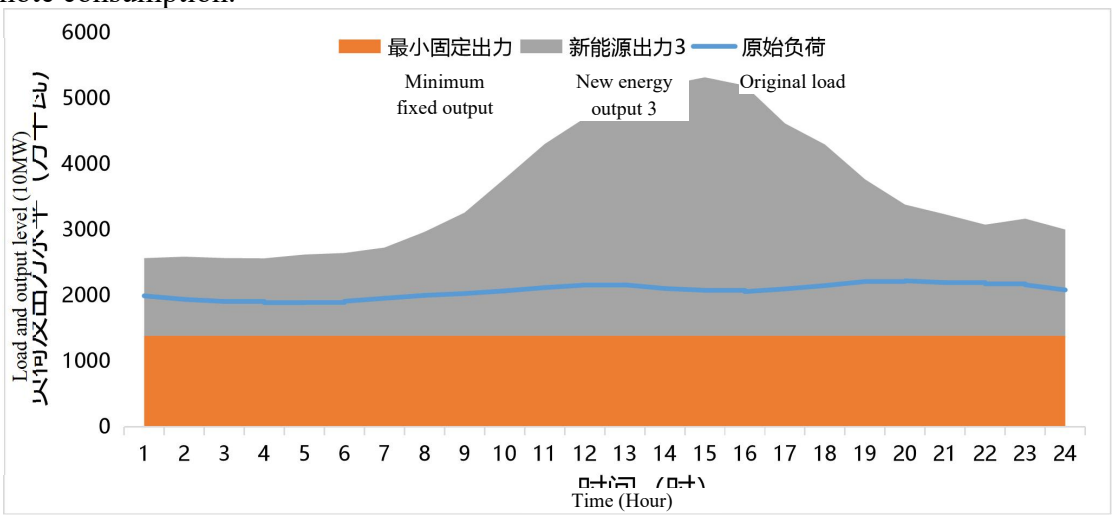

Figure 4 Energy Storage Promoting New Energy Consumption (Energy Abandonment at All Periods)

In general, if the $S_{\text{abandoned electricity}}$ represents the daily abandoned electricity of new energy, and the $S_{\text{discharge space}}$ represents the electricity space that can be discharged daily by the system, then:

(1) When $S_{\text{abandoned electricity}} < S_{\text{discharge space}}$, the role of daily regulated energy storage to promote new energy consumption is obvious, and there is no energy abandonment in the system;

(2) When $S_{\text{abandoned electricity}} = S_{\text{discharge space}}$, the inflection point of the role of daily regulated energy storage to promote new energy consumption appears;

(3) When $S_{\text{abandoned electricity}} > S_{\text{discharge space}}$, the addition of new daily energy storage cannot further improve the effect of new energy consumption, the system begins to abandon energy,

and multi-day, weekly, monthly regulation and other longer cycle energy storage are required.

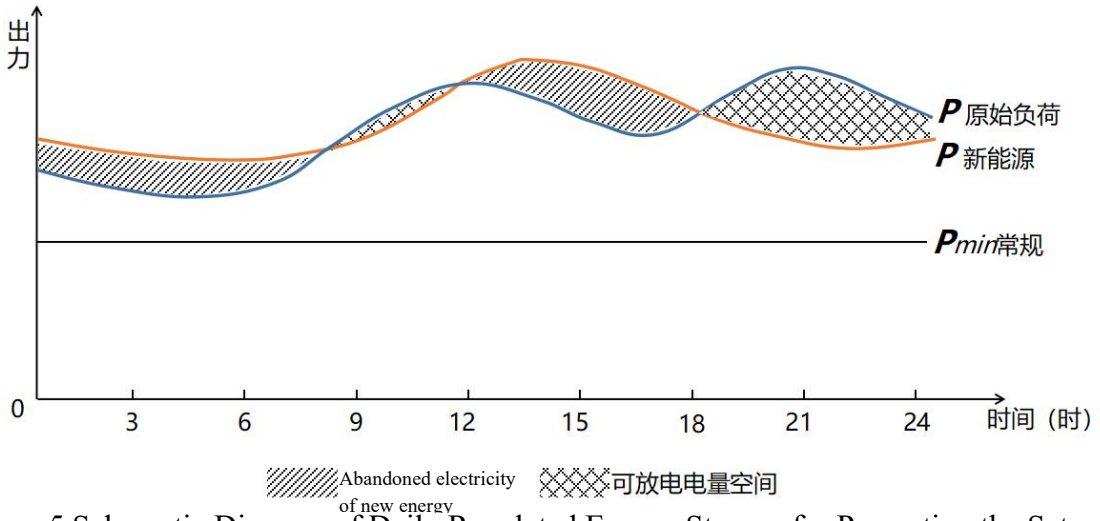

Figure 5 Schematic Diagram of Daily Regulated Energy Storage for Promoting the Saturation Effect of New Energy Consumption

3. Case study of daily regulated energy storage for promoting the saturation effect of new energy consumption

3.1 Case of daily regulated energy storage for promoting new energy consumption

In the case, a new energy province in Northwest China was taken as an example, with boundary conditions as follows: (1) local load demand: the maximum load of 27.19GW, the electricity consumption of 178TWH; (2) installed power capacity: hydropower of 10GW, coal-fired power of 36 GW, gas-fired power of 10MW, biomass power generation of 500MW, wind power of 33GW, photovoltaic power of 38 GW; (3) inter-provincial power flow: 8GW from Jiuquan to Hunan, 8GW from East Gansu to Shandong, and 8GW of power from East Gansu to Zhejiang; (4) energy storage duration: 4 hours. The new energy consumption and utilization results were derived from 8,760 hours of simulation throughout the year using the power production simulation tools.

Quantitative results showed that, under the high penetration rate of new energy, the improvement effectiveness of increasing daily regulated energy storage on new energy consumption would gradually weaken, and the new energy utilization would be gradually “saturated” with the increase in the scale of energy storage, so that it was “dangerous” to rely entirely on the daily regulated energy storage for new energy consumption. A new energy province in Northwestern China was taken as an example. Given the installed capacity of 71GW of new energy generation in 2025, accounting for 60%, the daily regulated energy storage scale was increased from 0 to 8GW, and the new energy utilization rate was increased by 3.4 percentage points, but continued to increase by 8GW to 16GW, with the utilization rate increased by 0.37 percentage points only, i.e., the increase in new energy utilization rate promoted by the daily regulated energy storage per 1GW per day decreased from 0.43 percentage points to 0.046 percentage points. The detailed 8760 production simulation calculations showed that: in case of no energy storage, the new energy utilization rate was 85.1%, increasing by 8GW of energy storage, and the utilization rate was increased to 88.5%, which could absorb an additional 9.27TWH of new energy electricity. However, the increase in energy storage from 8GW to 16GW can only raise the utilization rate to 88.87%, absorbing an additional 1.09TWH of new energy electricity.

It can be seen that **a continuous increase in the daily regulated energy storage scale cannot lead to an equivalent increase in the new energy utilization rate.** As shown in Figure 6, the effect of daily regulated energy storage on promoting consumption is gradually weakening, and after the scale of storage exceeds the “saturation point” (a turning point where the effect of

promoting consumption decreases significantly), the increase in new energy utilization rate slows down sharply. **The above phenomenon debunks the idealized understanding of "meeting all requirements by using energy storage" in the current energy industry, that is, it cannot be simply assumed that "new energy + energy storage" can completely solve the problem of consumption.**

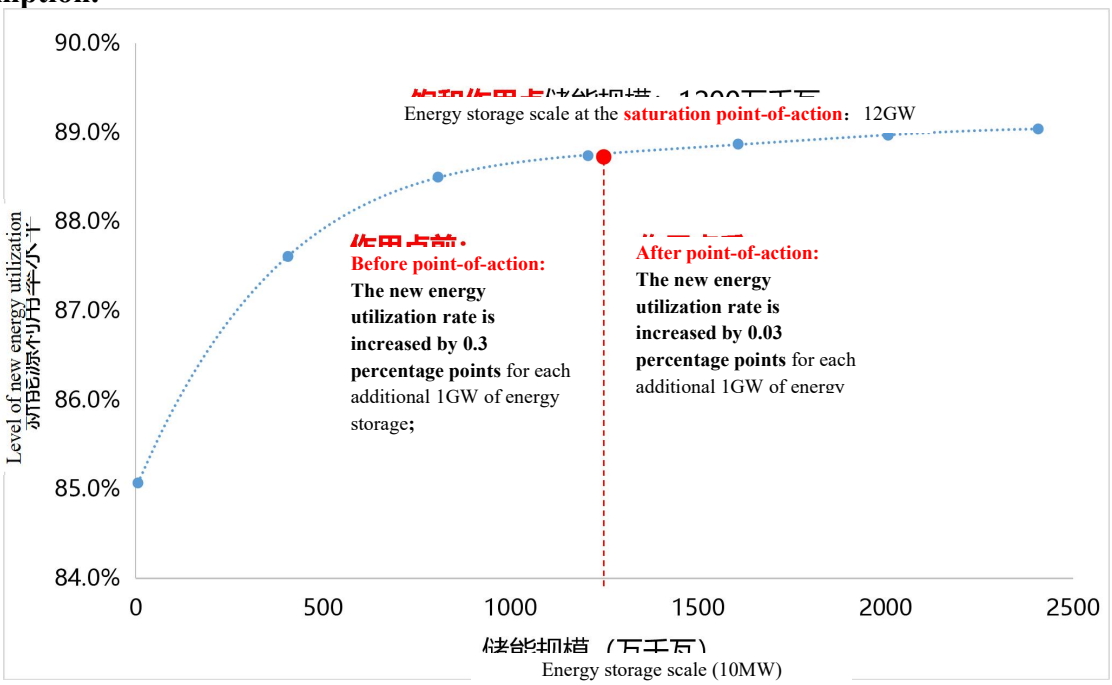

Figure 6 Saturation Effect of Daily Regulated Energy Storage on Promoting New Energy Consumption

The reason for the "saturation effect" of daily regulated energy storage for promoting consumption is that, under the high penetration rate of new energy, the phenomenon of continuous wind and PV abandonment occurs frequently, resulting in "nowhere to discharge" of daily regulated energy storage in the short-term cycle. With the installed capacity proportion of new energy increases, when energy abandonment evolves from a short period of time to a continuous and long period of time, it is difficult to discharge the electricity stored in the daily regulated energy storage, and the effect of increasing the scale of energy storage on improving the new energy When energy abandonment evolves from a short period of time to a continuous and long period of time, it is difficult to release the electricity stored in the daily regulated energy storage, and the effect of increasing the scale of energy storage on improving the new energy utilization rate will be weakened and tend to saturation.

3.2 Upper limit of new energy utilization rate

For a high proportion of new energy power systems, even if various measures are taken, it is still difficult for the new energy utilization rate to reach 95%, and the phenomenon of the "utilization rate ceiling" will occur. Taking Gansu as an example, under the scheme of 60% and 70% installed capacity penetration rates of new energy, the "saturation points" of daily regulated energy storage appear around 12GW and 8GW, respectively, with corresponding daily regulated energy storage accounting for 17.0% and 7.3% of the installed capacity scale of new energy, and the new energy utilization rates of 88.7% and 70.0%, respectively. The daily regulated energy storage is continuously increased on a large scale, while the new energy utilization rate has increased extremely slowly, **and is difficult to exceed 90% and 72%, which is called the "utilization rate ceiling". The higher the penetration rate of new energy, the lower the "utilization rate ceiling" of the system, which needs to be taken into account when the utilization control goals are planned for various regions. Increasing multi-day, weekly, monthly, and quarterly regulation of energy storage and other longer-term energy storage**

can continue to improve the new energy utilization rate, but it is expected that it will be difficult to apply the above types of energy storage on a large scale during the "14th Five-Year Plan" and the "15th Five-Year Plan".

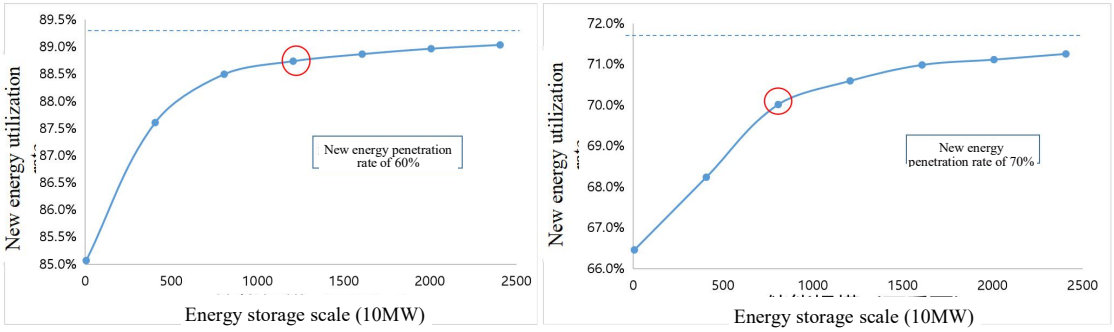

Figure 7 Comparison of Energy Storage Saturation Points-of-Action under Different New Energy Penetration Rates

3.3 Role of other measures to promote new energy consumption

Measures to promote new energy consumption, such as flexibility transformation of thermal power and increase in external transmission channels, do not have a "saturation effect" and should be prioritized in flexible resource planning. The flexibility transformation of thermal power can reduce the integrated minimum technical output level of the system throughout the entire time period, and the increase in external transmission channels can increase the equivalent load level of the system throughout the entire time period [6]. Therefore, these two types of measures can directly expand the consumption space of the system throughout the entire time period without a saturation effect. As shown in Figure 8, as the scale of flexibility transformation continues to improve, the integrated minimum technical output of coal-fired power continues to decrease (the average peak regulation depth continues to increase), and the new energy utilization rate is increasing linearly. Taking the above scenario of a 60% penetration rate of installed capacity of new energy in the new energy province of Northwest China as an example, when the daily regulated energy storage reaches the "saturation point", it is difficult to significantly improve the utilization rate by increasing energy storage continuously. However, if another 8GW of thermal power units are transformed flexibly, 800MW of downward regulating capacity can be released, and the new energy utilization rate can be increased by nearly 3 percentage points.

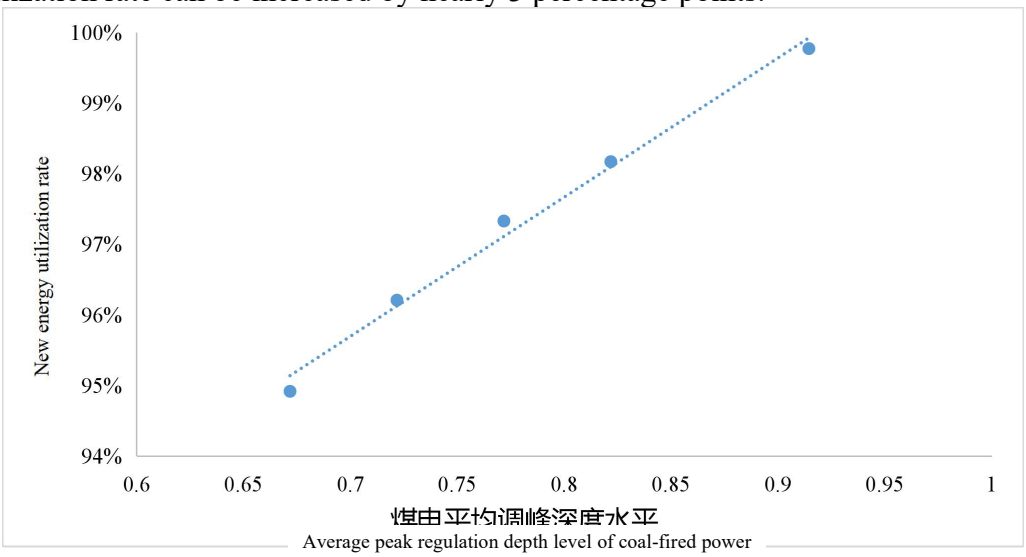

Figure 8 Improvement of New Energy Utilization Rate by Flexibility Transformation of Thermal Power

4. Suggestions

The development of energy storage has had a significant impact on the planning and policies for the new energy consumption during the 14th Five-Year Plan and the 15th Five-Year Plan. It should report and communicate with government authorities promptly to guide the scientific establishment of the positioning of energy storage and promote the healthy and sustainable development of the industry.

Firstly, it involves accurately categorizing energy storage types and strategically deploying various adaptable energy storage facilities. The classification of energy storage types should be standardized and refined, encompassing different types of regulation capabilities, such as daily, multi-day, weekly, monthly, seasonal, and yearly adjustments. The economic efficiency and "saturation effect" should be taken into consideration. Diverse and rational configurations of flexible regulation resources, including various types of energy storage, should be implemented in different periods and regions. For regions in China, particularly North China, Northwest China, and Northeast China, where the proportion of renewable energy is relatively high, priority should be given to measures that do not exhibit saturation effects, such as the flexible transformation of thermal power, increasing power transmission to other areas, and demand-side response. Daily regulation energy storage should only be used as an auxiliary and supplementary measure.

Secondly, the utilization rate control targets for all regions should be set based on the local conditions of each region. For regions with a high proportion of new energy, the "one-size-fits-all approach" is not economical and feasible technically for the sake of ensuring a 95% utilization rate. Hence, there is a necessity to calculate the "utilization rate caps" of all regions in a rolling manner and set reasonable utilization rate control targets according to local conditions and appropriate time with a comprehensive consideration of system costs.

Acknowledgments

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