Analysis of Typical Independent Energy Storage Power Station Operation Data

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ABSTRACT

Joint optimization planning of new energy, energy storage, and power grid is very complex task, and its mathematical optimization model usually contains a large number of the variables and constraints, some of which are even difficult to accurately represent in model. The study shows that the charging and the discharging situations of the six energy storage stations (the Dayan Energy Storage Station) on September 1st were respectively counted. All six stations were charged during the low valley period in the evening (0:00-8:00), discharged during the peak period in the afternoon (12:00-14:00) for the first time, charged at the same level in the afternoon (17:00-20:00), and discharged during the peak period in the evening (20:00-22:00) for the second time. Daily power generation of each month exhibits the unique operating pattern, and the overall trend of power generation gradually increases in the first 8 months. And power generation characteristics of two typical energy storage power stations within 1-31 days are similar, with the main difference being that there are certain differences in the specific power generation.

Keywords: Digital twin model, singular value decomposition (svd), pod reduction algorithm, calculation efficiency

1. INTRODUCTION

The six energy storage power stations all respond to the charging and discharging strategies of the project based on the current time of use electricity price rules. Generally, the charging and discharging strategies are implemented according to the valley charging peak discharge, the valley charging peak discharge(peak valley/peak valley), and the flat charging peak discharge(peak flat)[1-3]. The price of independent energy storage charging and discharging is slightly lower than that of commercial time of use electricity. Average time of use electricity price in 2024 is shown in the table below[4].

Table 1. Average time of use electricity price.

Time-sharing period	Electricity price(yuan/kWh)
Sharp section	0.8729
Peak segment	0.72094
Flat section	0.43818
Valley section	0.16912

As shown in the figure below, the charging and the discharging situations of six energy storage stations (Dayan Energy Storage Station) on September 1st were respectively counted. All six stations were charged during the low valley period in the evening (0:00-8:00), discharged during the peak period in the afternoon (12:00-14:00) for the first time, charged at the same level in the afternoon (17:00-20:00), and discharged during the peak period in the evening (20:00-22:00) for the second time[5,6].

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The International Conference Optoelectronic Information and Optical Engineering (OIOE2024), edited by Yang Yue, Lu Leng, Proc. of SPIE Vol. 13513, 135133R · · 0277-786X · · doi: 10.1117/12.3054933

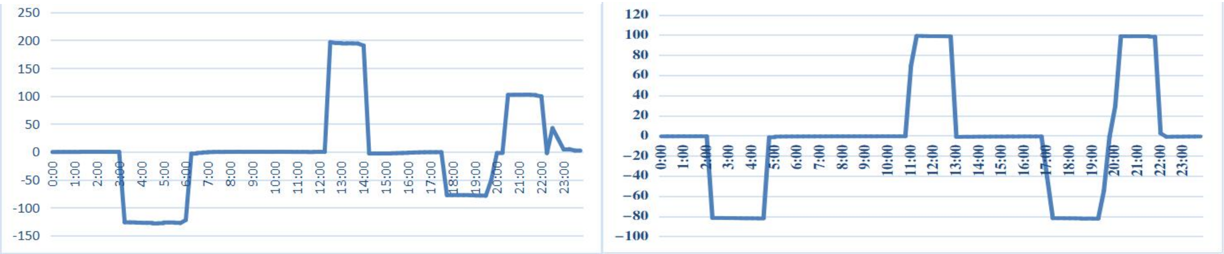

Figure 1. Typical charging and discharging characteristics of energy storage power plants within 24 hours.

During the period of September December 2023, the operation of independent energy storage on six grid sides will vary. From the perspective of the number of operation calls, except for Dayan Energy Storage Station which did not perform charging and discharging, the Science Valley and Huaiyuan Energy Storage Stations achieved 96 days and 102 days of charging and discharging respectively. The Songhui and the Longsheng Energy Storage Stations only charged and discharged once a day for more than 50 days[7,8], and the Songhui Energy Storage Station did not perform charging and discharging at all for 11 days.

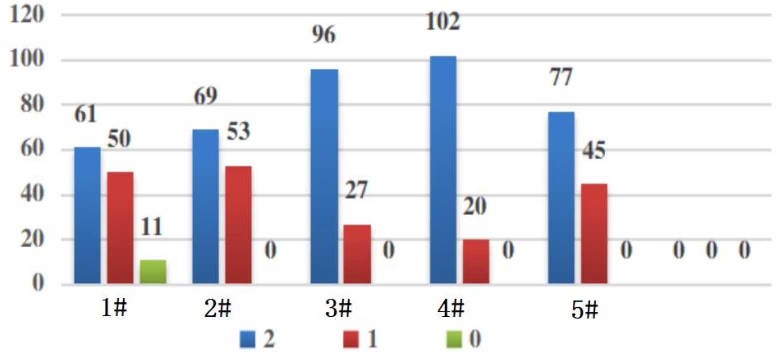

Figure 2. Energy storage operation and utilization in 2023.

From the perspective of the proportion of the operational calls, the Dayan Energy Storage Station has not carried out charging and discharging, while the other five energy storage stations have a charging and discharging ratio of over 50%. The proportion of 2 charging and 2 discharging calls at Science Valley and Huaiyuan Energy Storage Station is 78.05% and 83.61%, respectively[9].

Figure 3. Energy storage operation and utilization in 2024.

During the period of January 1st to August 20th, 2024, there was a significant decline in the number of calls to energy storage stations. Only Huaiyuan Energy Storage Station achieved over a hundred times of 2 charging and 2 discharging, accounting for 40.34% of the calls, and only achieved 1 charging and 1 discharging in nearly half of the time. Songgai, Longsheng, Science Valley, Huaiyuan, and Shuanghuai stations all have not been charged or discharged for more than a month, and the Dayan Energy Storage Station has not been charged or discharged for 196 days, which is equivalent to 84.12% of the non operating time.

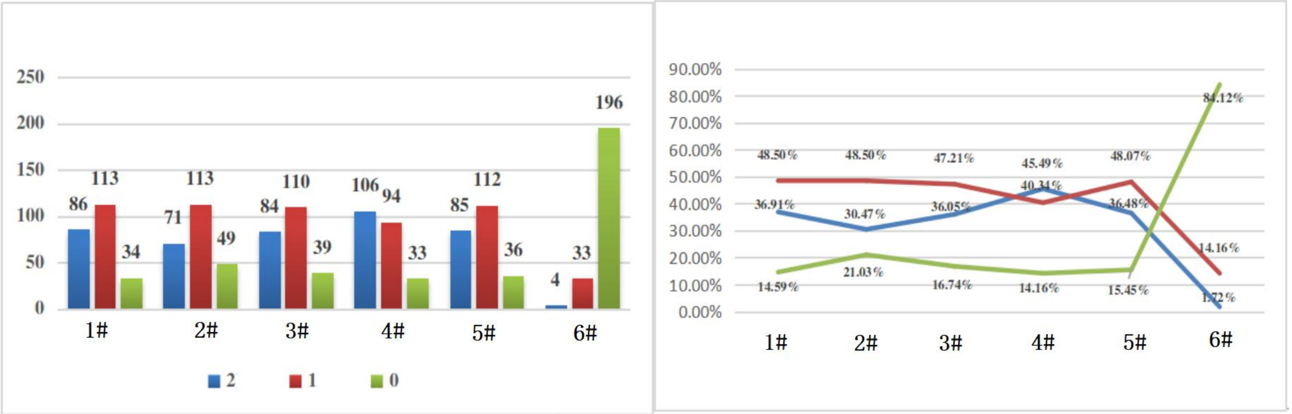

Figure 4. Energy storage operation and utilization in 2024.

2. CONSIDERING THE CONSTRAINTS OF POWER SYSTEM FLOW BALANCE UNDER ENERGY STORAGE CONDITIONS

Joint optimization planning of new energy, energy storage, and power grid is a very complex task, and its mathematical optimization model usually contains a large number of the variables and constraints, some of which are even difficult to accurately represent in model. Traditional mathematical methods for optimization usually have a very complex solving process and rely heavily on accuracy, so traditional mathematical programming methods are limited. Genetic algorithm, particle swarm optimization algorithm, and simulated annealing algorithm are all intelligent algorithms, and using them individually or in combination has significant advantages in solving model optimization problems. The mathematical meaning of scene reduction can be expressed as follows[10]. Let the scenario and the probability of the scenario be and, respectively, and at this point, the reduced functional of the scenario can be expressed as:

$$f = \min\left\{ \sum_{i=1}^{n}\sum_{j=1}^{m} c\left(\omega_i,\tilde{\omega}_j\right)\eta_{ij} : \eta_{ij} \geq 0, \sum_{i=1}^{n}\eta_{ij} = q_j, \sum_{j=1}^{m}\eta_{ij} = p_j, \forall i,j \right\} \tag{1}$$

A scene is defined as a sequence:

$$\omega_i = \left\{\lambda_i^1,\ldots,\lambda_i^k,\ldots,\lambda_i^{n_T}\right\}, i = 1,\ldots,n_s; k = 1,\ldots,n_T \tag{2}$$

The distance between scenes is:

$$d\left(\omega_i,\tilde{\omega}_j\right) = \left(\sum_{k=1}^{n_T}\left(\lambda_i^k - \tilde{\lambda}_j^k\right)^2\right)^{\frac{1}{2}} \tag{3}$$

Identify the scenarios that need to be reduced and eliminate those that meet the following conditions:

$$\rho_t\rho_i \min d\left(\omega_t,\omega_i\right) = \min_{x\in\{1,\ldots,n_s\}} \rho_x \left\{ \min_{y\in\{1,\ldots,n_s\},y\neq x} \rho_y d\left(\omega_x,\omega_y\right)\right\} \tag{4}$$

This step deleted the scene with the closest probability distance to other scenes. Otherwise, important information may be lost due to the exclusion of the scene that is significantly different from other scenes; This heuristic method not only considers the distance between scenes, but also takes into account the probability of the scenes. Scenes with the low probability and lack of representativeness are more likely to be excluded.

$$d\left(\omega_t,\omega_{t'}\right) = \min_{t\neq t'} \rho_t\rho_{t'} d\left(\omega_t,\omega_{t'}\right) \tag{5}$$

Considering that there are not too many suitable energy storage sites within the power supply area of a single substation, it is often not suitable to determine energy storage site selection through optimization methods in practical applications. The role of the energy storage in supporting new energy access is mainly to prevent voltage exceeding limits and current overload problems[11]. Therefore, when determining energy storage point, weak nodes with stable voltage are selected.

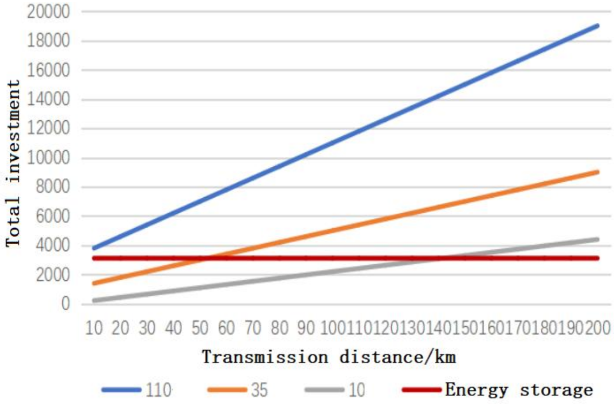

Figure 5. Total investment in remote areas with different transmission distances (considering energy storage).

According to calculations in Figure 5, when energy storage investment is fixed and impact of altitude and construction environment is not considered, using the 110kV voltage level transmission does not have the economic viability. When the transmission distance exceeds the 50 kilometers, using the 35kV voltage level transmission is not economical. It is not economical to use the voltage level of the 10kV when the transmission distance exceeds 140 kilometers.

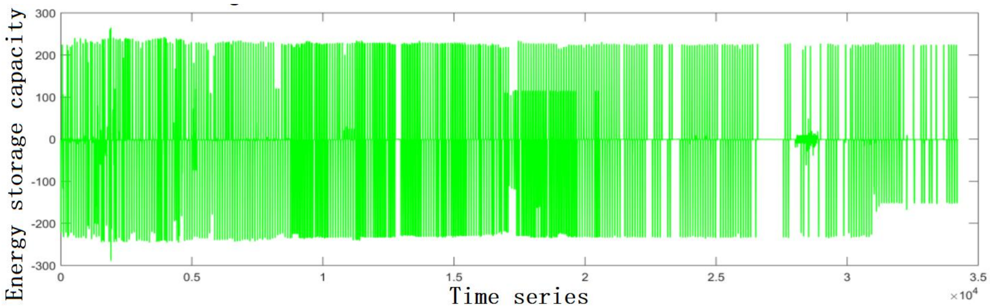

Figure 6. 35000 data points for charging and discharging of the energy storage power station.

As shown in Figure 6, there are 35000 data points for charging and discharging of the energy storage power station. It can be seen that the energy storage capacity obtained by the above planning method fluctuates between -200MW and 200MW. The first 20000 data points are denser, and subsequent data points are sparser, indicating that the subsequent charging and discharging times of the energy storage power station are fewer.

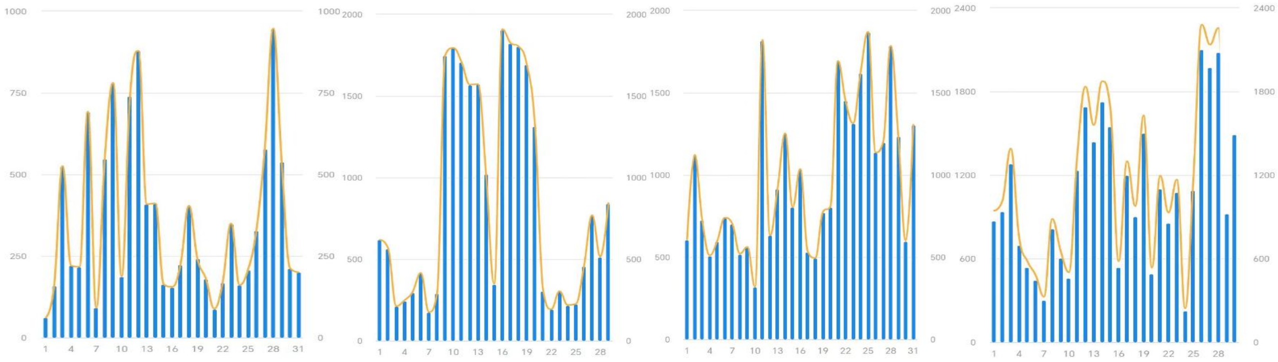

Figure 7. Total investment in remote areas with different transmission distances (considering energy storage).

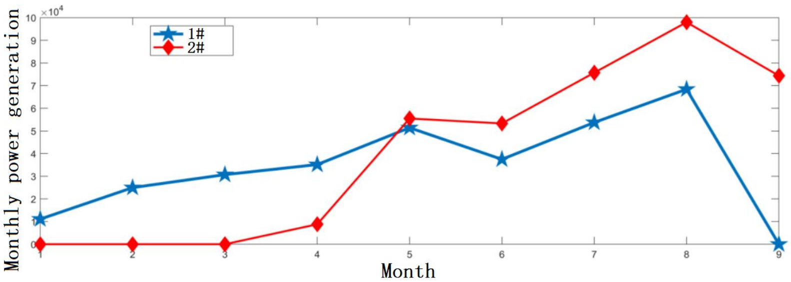

Figure 8. Total investment in remote areas with different transmission distances (considering energy storage).

The figure 7 shows the power generation of a typical energy storage power station over the course of 8 months. It can be seen from the figure that the daily power generation of each month exhibits the unique operating pattern, and the overall trend of the power generation gradually increases in the first 8 months. And the power generation characteristics of two typical energy storage power stations within 1-31 days are similar, with the main difference being that there are certain differences in the specific power generation. Specifically, the quantitative comparative analysis will be conducted on the power generation curves of the two typical energy storage power stations within 31 days of June, observing their output characteristics, comparing the power generation situation of the two adjacent typical energy storage power stations, and analyzing the internal reasons for the insufficient power generation of one of the energy storage power stations.

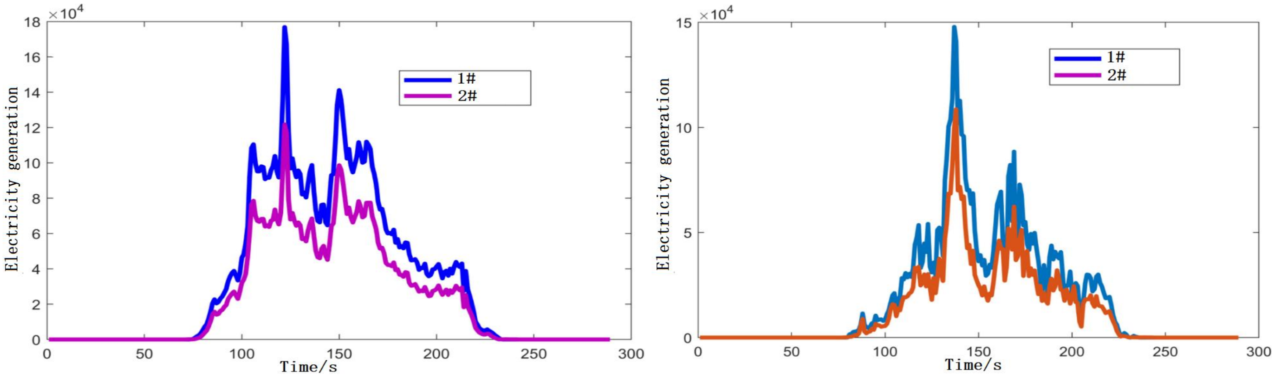

Figure 9. Output curve of photovoltaic energy storage power station under 2 typical days.

Figure 9 shows that comparing the output of a typical photovoltaic energy storage power station on two typical days, it can be seen that the trend of the two curves is basically the same, except for a certain deviation in specific values. For the typical power station on June 1st, dividing by 1.5782 can move them to same baseline. Similarly, for the typical power station on June 2nd, dividing by 1.6280 can move them to the same baseline. Therefore, there are basic rules that can be followed for both.

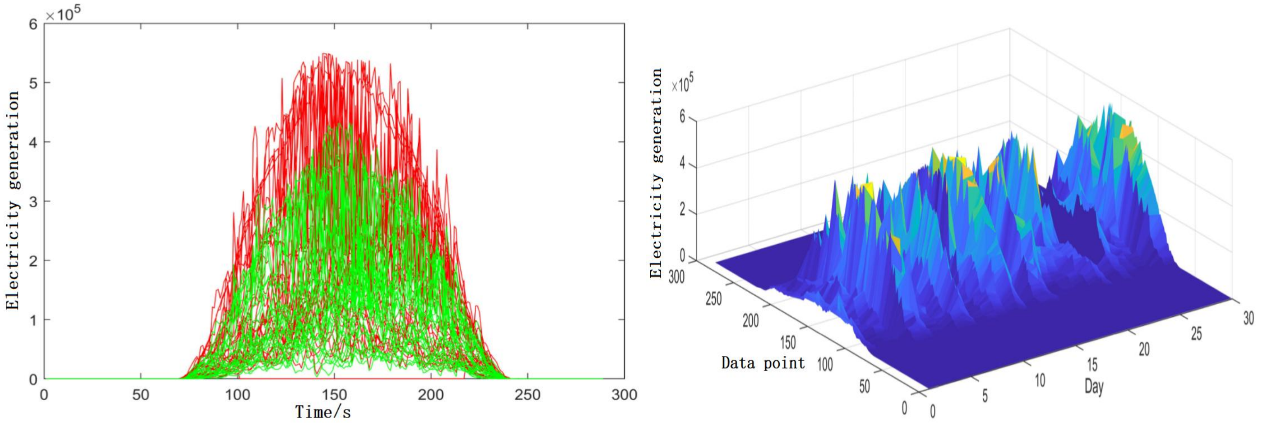

Figure 10. 3D view output curve of photovoltaic energy storage power station under 2 typical days.

Figure 10 shows that for June, it can be seen that the power generation of typical power station 1 can effectively cover that of typical power station 2. It is precisely because of the inverted "V" distribution of the Dazu Wanyuhong project that there is a certain difference in photovoltaic power generation efficiency between the two. By converting the equipment information, production processes, etc. in distributed photovoltaic power plant system into digital expressions, and through advanced digital capabilities such as the digital IoT device monitoring, the intelligent analysis, and digital autonomy, the evolution of the physical world and digital space from virtual to real mapping to deep interaction is completed, thereby achieving the digital twin and online+offline interaction integration of the entire power plant system, and realizing the construction, management, and service efficiency enhancement of distributed photovoltaic power plants.

3. CONCLUSION

The power generation characteristics of two typical energy storage power stations within 1-31 days are similar, with the main difference being that there are certain differences in the specific power generation. Specifically, the quantitative comparative analysis will be conducted on the power generation curves of the two typical energy storage power stations within 31 days of June, observing their output characteristics, comparing power generation situation of the two adjacent typical energy storage power stations, and analyzing the internal reasons for the insufficient power generation of one of the energy storage power stations. It is precisely because of the inverted "V" distribution of the Dazu Wanyuhong project that there is a certain difference in photovoltaic power generation efficiency between the two. For the typical power station on June 1st, dividing by 1.5782 can move them to same baseline. Similarly, for the typical power station on June 2nd, dividing by 1.6280 can move them to the same baseline. Therefore, there are basic rules that are followed for both.

ACKNOWLEDGMENTS

This article is sponsored by the Chongqing Electric Power Company's technology project (2024 Yudian Technology 43#).

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