Research on energy storage capacity analysis and short-term load prediction method for new energy high penetration system

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Abstract: The uncertainty of high penetration new energy is strong. After the proportion of electric units is reduced, the flexible resources are suppressed, and the system-level energy storage can effectively relieve the frequency modulation pressure. In this paper, an energy storage capacity analysis method is proposed for new energy high permeability system. The short-term load is predicted by quantile regression analysis, so as to obtain the optimal peak regulation and frequency modulation frequency in operation, so as to further analyze the relationship between new energy permeability, capacity and energy storage power. The results show that the analytical method proposed in this paper can determine the demand capacity of the new energy high permeability system.

1 Introduction

In recent years, China attaches great importance to environmental problems. Under such a social background, the penetration rate of new energy has increased, and the uncertainty of the power system has been strengthened, thus increasing the pressure of peak modulation and frequency modulation[1]. Energy storage is a flexible resource, which can regulate the peak and frequency modulation, so as to ensure that the high penetration system of new energy can cope with this uncertainty. At present, energy storage has been initially applied in the site, which not only has good economy, but also can make up for the shortcomings[2]. In this regard, this paper will analyze the energy storage capacity from the system level, and predict the short-term compliance. Through the generation method of QRA and Gaussian hybrid model, establish the optimization model, and obtain the optimized peak modulation frequency and frequency frequency, determine the energy storage demand, and analyze the relationship. This has a very important role in the construction of the configuration.

Scholars have discovered a coupled quantile regression analysis (QRA) method, which, when combined with clustering techniques, can characterize the uncertainty of new energy and has high applicability in non parametric probability prediction models. The current research on improving energy storage regulation capacity has attracted the attention of many scholars. Some studies have evaluated the potential of energy storage to participate in peak shaving and frequency regulation, while others have proposed a new method for peak shaving using a separate energy storage system. However, it cannot maximize the benefits of energy storage.

2 Uncertainty of the net load of the new energy high-penetration system

2.1. QRA sample processing

The reason why the net load is uncertain is that there is a large difference between the actual power and the predicted power, and the data amount is relatively large and the information is more[3]. QRA can effectively mine the relevant information in the data set and describe the characteristics of the corresponding variables. Therefore, QRA is mainly used in the sample processing of net load.If the probability of random variable y ≤ y is set to τ , then y τ is the τ quantile of y. The specific calculation method is shown in formula 1.

$$y_\tau = \left[y \middle| F(y) \le \tau \right] \tag{1}$$

Where F (y) is the probability distribution function.

The matrix was built and the matrix was set to Pr、Pf, thereinPr（i,j）、Pf(I, j) is the element of column j in row i, i represents the actual power on day i, and j represents the predicted power at the j th sampling point.support τ After setting to the quantile, the relationship between actual power and predicted power is shown in Equation 2.

$$P_{r,\tau}(i,j) = a_\tau p_f(i,j) + b_\tau \tag{2}$$

Among them, a τ and b τ are the actual power Pr in the τ percentile, and the lower linearity and parameter values of τ . In the calculation of a τ and b τ , formulas 3 and 4 can be used for calculation.

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$$\min Q(\tau)=\sum_{i=1}^{i}\sum_{j=1}^{j} f_{\tau}\left(p_r(i,j)+b_{\tau}\right) \tag{3}$$

$$f_{\tau}(x)=\begin{cases}\tau x, x\geq 0\\ (\tau-1)x, x\ \pi\ 0\end{cases} \tag{4}$$

Among them, Q (τ) is τ the objective function, f τ (x) is the test function, and i, j are the number of scenes and sampling points.

2.2. High-speed hybrid model scenario generation

Non-parametric probability prediction model is able to be effectively determined by QRA[4], With interpolation on the net load actual power PrThe quantiles of (i, j) were calculated. When Ti, j, interacts with (τ i,j) Equal, using the Probit function is able to fit the Gaussian distribution, thus forming the sample covariance array S. With the clustering method of Gaussian mixture model, the net load scenarios can be reduced to k net load scenarios, and the distribution probability P can be obtainedk,typ. The specific calculation formula is shown in 5.

$$P_{k,typ}=\begin{cases}\left[P_{r,1,1},P_{r,1,2}\cdots P_{r,i,j}\right]^T\\ \left[P_{r,2,1},P_{r,2,2}\cdots\right]^T\\ \cdots\\ \left[P_{r,k,1},P_{r,k,2}\cdots P_{r,k,j}\right]^T\end{cases} \tag{5}$$

In the formula, $\left[P_{r,1,1},P_{r,1,2}\cdots P_{r,i,j}\right]^T$ is the power vector in i net load scenarios.

3 Model optimization of frequency modulation and peak modulation of new energy high penetration system

3.1. Power calculation

In the process of system operation, it is necessary to meet the load requirements. Relevant plans should be made according to the load forecast power, and the uncertainty can be dealt with with the help of energy storage in the conventional units[5]. Before building an optimization model, the uncertain power needs to be calculated. The peak modulation power adjustment is kept to read for 15min, and the time scale of frequency modulation power adjustment is 5min. The calculation formula is shown in formula 6 and formula 7.

$$P_{s,t}^{u}=P_{s,t}-P_{t}^{nl,f} \tag{6}$$

$$P_{s,t,w}^{u}=P_{s,t,w}-P_{s,t} \tag{7}$$

among,Ps,tAnd Pus,tIs the uncertain power in the t period in s under the time scale of peak modulation. Ps,t,wAnd Pus,t,wIt is the uncertain power in the deployment stage of t period w in s under the time scale of frequency modulation; Pnl,ftIs the predicted power in the t period under the peak modulation time scale.

3.2. Joint model optimization

Through energy storage, it can respond quickly and participate in peak modulation and frequency modulation simultaneously. The first step determines the objective function, as shown in Equation 8.

$$\min F=\sum_{s\in\Omega}\rho_S\left\{\sum_{t\in T}\left[\sum_{i\in N_G}\left(f_{s,i,t}^{G,op}+f_{s,i,t}^{G,pr}+f_{s,i,t}^{G,ss}+f_{s,i,t}^{G,ss}\right)+f_{s,t}^{G,pr}+f_{s,t}^{E,re}\right]\right. \tag{8}$$

Among them, Ω is the scene set, T is the time series set, NG is the unit set, Ps is the probability of occurrence, and $\left(f_{s,i,t}^{G,op}+f_{s,i,t}^{G,pr}+f_{s,i,t}^{G,ss}+f_{s,i,t}^{G,ss}\right)$ is the function of operation, peak shaving, start stop, and backup for time period i in s. $f_{s,t}^{G,pr}+f_{s,t}^{E,re}$ is the standby function for peak shaving and frequency modulation during the st period in uncertain output scenarios.

4 Method of energy storage capacity

4.1. Construction of indicators

First, the deviation degree (Energy Storage Electricity Deviation, ESED) index is constructed. The climbing rate of energy storage is fast and the capacity is not high[6]In order to give full play to the capacity of energy storage, we need to pay attention to the balance of discharge. The ESED indicator was set to γ, as shown in Equation 9.

$$\gamma=\begin{cases}1-\dfrac{E_d}{E_c}, E_c\geq E_d\\ 1-\dfrac{E_c}{E_d}, E_c\ \pi\ E_d\end{cases} \tag{9}$$

Secondly, the OCGR index is constructed, and after adjusting the operating power, the operating cost of the conventional unit combined energy storage system will be affected to a certain extent. To reflect this impact, the OCGR is set to σ, as shown in formula 10.

$$\sigma=\frac{\left(f_{\cos t}(P_E)-F\right)}{F} \tag{10}$$

Among them, fcost (PE) is the cost function, and σ σ needs to be greater than 0. As the number increases, the cost will also increase. Therefore, the smaller the σ, the better.

4.2. Method of determining energy storage requirements

In the process of peak regulation calculation, the energy storage system will appear a lot of electric energy. At the same time, the effect of ESED indicators was more significant, after establishing the ESED and OCGR indicators, the model was corrected. For example[7], in the second section, the peak power, maximum charging power, maximum discharge power, discharge power and charging power are optimized, because it will be affected by the solution speed and difficulty, and the value range needs to be reduced.

Scene operation process, can according to the scene of energy storage peak load maximum value to determine the rated power, and according to the maximum discharge and charging the rated capacity of energy storage system, can build a new time set, {Ml | l=1,2, Ls}, Ls is in the number of scene s, Ml is in l charge / discharge time set, set the peak demand power to p Γ_s Epr,s,max, Set the peak load demand capacity to EEpr,s,max, See Equation. 11 for details[8].

5 Example data analysis

5.1. Data source

The actual and predicted power of load, wind power and photovoltaic power all come from a power grid[9]. The thermal power unit is used as a conventional power supply, with 8 units with a capacity of 5720MW. The total photovoltaic capacity is 2,307 MW and the total capacity of wind power is 2,356 MW. A total number of 10 scenarios was set using the QRA. When the thermal power unit is running, a total of two weight values are set, and the two weights are α 1 and α 2, which are equal to 0.5.

5.2. Scene generation results

After sorting the current power grid data, the fitting characteristics of load QRA were found. There were 10 scenarios divided into 6 typical days (25,31,42,2111,208,267 days respectively), and the net load error was low, covering all possibilities. The specific results are shown in Table 1.

Table 1 Probability of occurrence in different scenarios, typical days

scene	Typical day 1	Typical day 2	Typical day 3	Typical day 4	Typical day 5	Typical day 6
1	5.55	20.92	9.29	8.22	8.77	9.59
2	23.22	3.84	9.86	5.48	3.29	8.49
3	15.62	19.45	6.03	8.367	20.82	14.25
4	11.78	3.56	24.79	4.19	4.11	6.03
5	6.30	11.23	15.62	5.21	23.29	9.59
6	2.74	13.97	6.19	4.11	1.10	12.32
7	7.40	3.56	9.59	17.26	3.01	2.47
8	18.90	11.51	6.03	7.40	14.25	26.59
9	0.82	10.14	2.19	26.04	16.82	1.64
10	7.67	1.82	10.41	13.42	4.54	9.03

5.3. Analysis of the results after joint optimization

First of all, the demand capacity of energy storage is determined. The correction of the change of ESED index before and after the operation of energy storage can reflect that the ESED index is reduced in different typical days, indicating that the imbalance of energy storage charging and discharge is improved. The operating cost before and after the correction is shown in Table 2. It is found that the cost increase is not obvious, indicating that the imbalance of charging and discharge can be improved through a small cost, as shown in Table 2.

Table 2 compare operating costs before and after correction

Typical day	Pre-amendment cost (ten thousand yuan)	Pre-amendment cost (ten thousand yuan)	recruitment
1	1886.42	1913.85	27.43
2	2102.19	2137.53	35.34
3	2025.26	2066.19	40.93
4	1774.80	1781.02	6.22
5	1686.80	1703.45	16.65
6	1645.69	1665.90	20.21

5.4. Analysis of energy storage demand results of new energy penetration

Different new energy penetration rates were set. A total of five different penetration rates were set in this study: 25%, 35%, 45%, 55% and 65%. The specific results are shown in Figure 1.

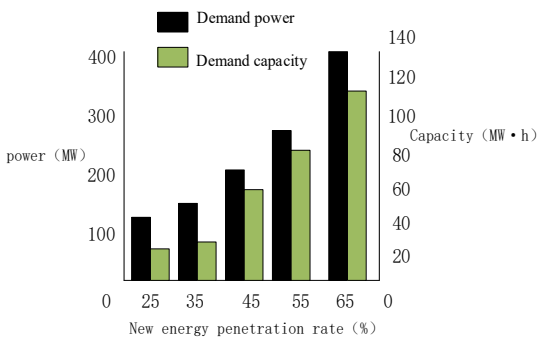

Figure 1 Comparison of demand power and demand capacity under different new energy permeability rates

6 Conclusion

Based on the increase of peak regulation and frequency modulation pressure in the new energy penetration system, the energy storage demand capacity of the system level is determined, and the short load prediction is studied, and two conclusions are drawn. First, in the case of uncertain net load, the determination method of high permeability system of new energy is proposed, and it is found that the error power basically meets the high-speed distribution, and has high predictivity and accuracy. The second is to analyze the new energy permeability. Based on different new energy permeability, it is found that the peak modulation working time increases significantly, and the frequency modulation working time does not increase significantly. Based on the research results of this paper, it can produce theoretical significance for the energy storage and load prediction of the new energy high penetration system. However, the research in this paper is not deep enough. We hope to carry out more in-depth research in the future work, so as to provide theoretical guidance for the high penetration of new energy[10].

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