Research on the Evaluation Model of Physical Asset Management Maturity of China's Inter-provincial Grid Enterprises

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Abstract—A comprehensive evaluation of the physical assets of power grid enterprises is conducive to promoting the management of assets of enterprises and avoiding the loss and waste of state-owned assets. This paper collects the objective statistics of the enterprise and the subjective scoring data of the experts in the index system for the past 5 years, and determines the comprehensive weight of each index through the combination of subjective and objective weights. Grey correlation and topsis method is used to establish a dynamic evaluation model for objective data to capture the trend of the comprehensive value of physical assets, and subjective data is used to establish a maturity model to calculate the maturity level of physical assets. In this way, the results of dynamic assessment and maturity assessment are combined to obtain the results of grid enterprise asset evaluation under multi-dimensional dynamic perspective. Finally, an empirical analysis using a grid data shows that the company should learn from the scientific management experience of 2016, maintain a high level of asset structure and utilization efficiency, and focus on improving the optimal management of asset decommissioning and health.

Keywords-Physical assets of power grid; comprehensive evaluation; indicator system; maturity model

1 INTRODUCTION

With the deepening of China's power grid in UHV, new energy, rural grid transformation and electric vehicles, the scale of investment in power grid assets is increasing. At the end of 2018, the national trans-regional power transmission capacity increased by 481.9 billion kW. In 2017, the length of AC transmission lines increased by 58084km, 1406km more than in 2016, and the DC transmission lines and converter capacity increased by 8339km and 79 million kW respectively, effectively improving the ability of cross-regional energy optimization configuration management. At the same time, the complexity of work such as asset types, investment scale, maintenance and renewal has increased correspondingly, and the scientific comprehensive evaluation of power grid physical assets is of great significance for optimizing asset structure and improving asset utilization efficiency.

ICEMME 2022, November 18-20, Nanjing, People's Republic of China

DOI 10.4108/eai.18-11-2022.2327155

At present, the comprehensive evaluation research on the power industry is relatively rich, and the evaluation angle mainly focuses on the reform of the power system and the development of the power grid: (1) The reform of the power system. Aiming at the risks of market price fluctuations and uncertainty in demand behavior faced by market participants, Namalomba Ellen et al[1] studied the pricing and bidding behaviors of power generation and electricity sales companies in a centralized electricity trading market with elastic demand. Xun Lu et al[2] constructed a comprehensive evaluation index system for distribution network planning under multiple levels, and set up a comprehensive evaluation model for smart distribution network planning under the new pattern of the power market to achieve the coordination and unity of individual and group interests. As an emerging transaction entity, distributed energy systems have difficulties in evaluation. Current research mainly focuses on new energy power stations, and there are few studies from independent power grid companies[3,4]. Guopeng Zhao et al[5] combined subjective and objective evaluation methods, and proposed a comprehensive evaluation method for AC/DC hybrid microgrid planning based on analytic hierarchy process and entropy weight method, and evaluated the problems by establishing a multi-attribute weighted decision model. (2) In terms of power grid development, scholars are concerned about the balance of power and electricity[6], the establishment of distributed energy systems[7], the grid connection of power terminals[8], the operating conditions of power enterprises[9-11], and customer satisfaction[12,13] and The demand and pricing of power projects[14] are evaluated and discussed, the complex indicators are streamlined, and the method of analytic hierarchy and entropy weight combination is used to determine the indicator weight, which makes up for the shortcomings in the single subjective or objective weight determination process. Some scholars have also conducted research on the current development level of power grids[15,16], used the method of cluster analysis to classify provincial-level power supply companies according to power supply quality indicators, and identify the gap between standard companies and industry benchmarks, so as to continuously improve management levels and benefits. Xie, P et al[17] started from China's power productivity and obtained the regional differences and characteristics of the development of the power industry in different regions of China. Cui Wencong et al[18] used Multiscale Geographically Weighted Regression (MGWR) to analyze the relationship between China's municipal industrial GDP and employment and industrial electricity consumption, and explored the relationship between energy consumption and economic growth and its importance of sustainable development. However, the evaluation of physical assets of the power grid is slightly weak. The perspective only exists on the entire power grid and a single device. For example, Niu Dongxiao et al[19] comprehensively evaluate the management risks of the physical assets of the power grid based on the life cycle cost management theory. Chilaka Ranga et al[20] proposed a new fuzzy logic model based on multiple criteria to determine the overall health index of the transformer.

Existing research is of great significance to the stable development of the power industry, but there are two shortcomings: First, with the technological innovation of the power grid and the expansion of the scale of investment, the scientific evaluation of physical assets should also be updated and promoted. However, the current research on the physical assets of the power grid is relatively weak; second, the evaluation object is at the national level or a single regional level, and it is difficult to detect the differences in the strengths and weaknesses of the physical asset management levels of various power grids. In view of this, this paper collects the objective statistical data of the physical assets of 27 provincial power grid companies to build a power grid physical asset evaluation system, and uses a combination of subjective and objective methods to determine the weights of comprehensive indicators; secondly, gray correlation and ideal solutions are used to establish provinces comprehensive evaluation model for international power grids, and use the maturity evaluation model to measure the maturity level of each provincial power grid indicator; finally, based on the empirical results, suggestions and work prospects are put forward.

2 COMPREHENSIVE EVALUATION MODEL OF POWER GRID PHYSICAL ASSETS

2.1 Weights of subjective and objective comprehensive indicators

The analytic hierarchy process and entropy method are two common weight determination methods [21,22]. The former focuses on the subjective will of experts in scoring and has specific human defects; the latter objectively determines the weights based on the variability of the indicators, which requires high quality of indicator data. This paper draws on the method of Guopeng Zhao [5] and constructs a method for calculating the weights of subjective and objective comprehensive indicators as shown in formula (1).

$$w_j = w_j^1 H_j + w_j^2 (1 - H_j) \tag{1}$$

Where w_j is the comprehensive index weight; $w_j^1$is the weight obtained by the analytic hierarchy process; $w_j^2$is the weight obtained by the entropy weight method; H_j is the entropy value.

2.2 Power grid comprehensive sequencing model

The method of combining gray correlation and ideal solution[23-26] can calculate the relative post progress of the evaluation object, and measure the relative pros and cons of the evaluation object by the relative post progress size, and obtain the corresponding ranking results accordingly.

2.2.1 Solve for Euclidean distance

Establish an index matrix $Z=(Z_{ij})_{n\times m}$ of m indicators for n consecutive years, and perform dimensionless processing:

$$r_{ij} = z_{ij} \Big/ \left(\sum_{i=1}^{n} (z_{ij})^2 \right)^{1/2} \tag{2}$$

The standardized index matrix $R=(r_{ij})_{n\times m}$ is obtained, and the index matrix $M=(m_{ij})_{n\times m}=(w_j m_{ij})_{n\times m}$ is obtained by weighting the index matrix according to the comprehensive index weight. According to the maximum value of each index in the index matrix M, the optimal plan and the worst plan are formed. The optimal (poor) plan here is composed of the largest (small) value of the positive index and the smallest (large) value of the reverse index:

$$\begin{cases} M^+ = \{\max_{1\le i\le n} m_{ij} \mid j \in j^+ \mid, \min_{1\le i\le n} m_{ij} \mid j \in j^- \mid\} = (m_1^+, m_2^+, \cdots, m_n^+) \\ M^- = \{\min_{1\le i\le n} m_{ij} \mid j \in j^+ \mid, \min_{1\le i\le n} m_{ij} \mid j \in j^- \mid\} = (m_1^-, m_2^-, \cdots, m_n^-) \end{cases} \tag{3}$$

In the formula, j^+ is the benefit index sequence (the larger the value, the better); j^- is the cost index sequence (the smaller the value, the better). According to the positive (negative) ideal solution in the optimal (poor) plan, the Euclidean distance from the sample to be tested to the positive (negative) ideal solution can be obtained:

$$\begin{cases} L_i^+ = \sqrt{\sum_{j=1}^{n} w_j (m_{ij} - m_j^+)^2} \\ L_i^- = \sqrt{\sum_{j=1}^{n} w_j (m_{ij} - m_j^-)^2} \end{cases} \tag{4}$$

2.2.2 Solve the degree of grey relation

Solve the gray correlation coefficient between the sample and the positive ideal solution and the negative ideal solution:

$$\begin{cases} \gamma_{ij}^+ = (\min_i \min_j \triangle m_{ij} + \theta \max_i \max_j \triangle m_{ij}) \big/ (\triangle m_{ij} + \theta \max_i \max_j \triangle m_{ij}) \\ \gamma_{ij}^- = (\min_i \min_j \triangle m_{ij}' + \theta \max_i \max_j \triangle m_{ij}') \big/ (\triangle m_{ij}' + \theta \max_i \max_j \triangle m_{ij}') \end{cases} \tag{5}$$

In the formula, $\Delta m_{ij}=|m_j^+ - m_{ij}|$ and $\Delta m_{ij}'=|m_j^- - m_{ij}|$; $\max_i \max_j \triangle m_{ij}$ is the maximum difference between the two levels, $\min_i \min_j \triangle m_{ij}$ is the minimum difference between the two levels; θ is 0.5.

Based on this, the gray correlation coefficient matrices of the sample and the positive ideal solution and the negative ideal solution are $N^+=(\gamma_{ij}^+)_{n\times m}$, $N^-=(\gamma_{ij}^-)_{n\times m}$ respectively, and the gray correlation degrees of the sample i and the positive ideal solution and the negative ideal solution are respectively:

$$\begin{cases} N_i^+ = \frac{1}{n} \sum_{j=1}^{m} \gamma_{ij}^+ \\ N_i^- = \frac{1}{n} \sum_{j=1}^{m} \gamma_{ij}^- \end{cases} \tag{6}$$

Perform dimensionless processing on the gray correlation degrees N_i^+, N_i^- and Euclidean distances L_i^+ and L_i^- obtained above to obtain the corresponding n_i^+, n_i^- and l_i^+, l_i^-, and calculate the paste progress between the sample and the ideal solution:

$$\begin{cases} S_i^+ = \eta_1 l_i^- + \eta_2 l_i^+ \\ S_i^- = \eta_1 l_i^+ + \eta_2 l_i^- \end{cases} \tag{7}$$

In the formula, η_1 and η_2 are the adjustment coefficients of the posted progress, satisfying $\eta_1+\eta_2=1$, S_i^+ is the closeness of the sample to the positive ideal solution, and S_i^- is the closeness of the sample to the negative ideal solution.

In order to reflect the closeness of the annual sample and the ideal solution to the fluctuation trend, the relative posting progress can be calculated by the following formula:

$$\sigma_i = S_i^+ \big/ (S_i^+ + S_i^-) \tag{8}$$

By observing the relative progress of annual data, we can understand the dynamic trend of the evaluation object's physical assets over the years, and the measured relative closeness corresponds to the relative pros and cons of the evaluation results.

2.3 Maturity evaluation model

The above-mentioned comprehensive ranking model can only learn the relative comparative advantages of inter-provincial power grids. If the absolute level of internal indicators can be obtained, it can help grid companies to overcome the shortcomings of physical asset management to a certain extent. For this reason, this paper applies the maturity theory[27-29] to the comprehensive evaluation method of physical assets.

Maturity refers to the ability of management to reach a state that can ensure that the organization's goals are well achieved. Maturity is a measure that reflects maturity, which refers to the development process of organizational capabilities that must continue to improve over time, from immature to relatively mature to mature development[30]. The maturity model is a set of scientific systems and methods that characterize the process of a certain aspect of management ability from low-level to high-level to achieve sustainable development, and provides a set of intuitive, tangible and measurable indicators that can be better achieved the correct evaluation and recognition of its management capabilities within and outside the organization points out the direction for the organization to formulate and implement improvement plans.

The maturity model is basically the same in the composition of the evaluation system, and most of them use a combination of qualitative and quantitative evaluation methods. Commonly used maturity evaluation methods include: key process area method, questionnaire method, minimum area method, fuzzy comprehensive evaluation method and grey comprehensive evaluation method[31-33]. Among them, fuzzy mathematics and grey system theory are two main mathematical models for studying uncertain and incomplete information systems.

The advantage of the fuzzy comprehensive evaluation is that the mathematical model is simple and easy to grasp, and the evaluation effect is better for multi-factor and multi-level complex problems. It has a unique evaluation value for the evaluated object and is not affected by the object set of the evaluated object. Other branches of mathematics and models are difficult to replace. The biggest feature of gray system theory is that it has no strict requirements on sample size and does not require any distribution. This method reduces the randomness of the data through various processing, strengthens the internal connection of the data, and uses as little data as possible to establish a model to describe the system being evaluated. Compared with the fuzzy comprehensive evaluation method, the gray system theory is more convenient. It can not only evaluate the level of the evaluated object, but also can sort and select the best based on their gray comprehensive evaluation value when there are multiple participants participating in the evaluation. A maturity model with many evaluation indicators but incomplete evaluation information.

Due to the many and complex factors that affect the maturity of asset management capabilities, people can only choose a limited number of indicators for analysis when evaluating them. In addition, a considerable part of the selected evaluation index data cannot be obtained from statistical data. Therefore, the system has the characteristics of incomplete information or "greyness". It can be seen that the maturity of comprehensive management capability is a gray system, so this article will use the gray comprehensive evaluation method to evaluate its maturity.

The physical asset management level of the power grid is divided into five levels as shown in Table 1: initial level I, growth level II, standard level III, mature level IV and excellent level V.

TABLE 1. MATURITY LEVEL DESCRIPTION

Grade	Description
I	The evaluation object has a basic understanding of physical assets
II	Appraisal objects have conceptual emphasis on physical assets
III	The evaluation object has a strategic emphasis on physical assets and establishes a related management system
IV	The evaluation object has sufficient practical experience for physical assets, and the relevant management system is fully applicable
V	The evaluation object truly achieves an excellent management model for physical assets, and sustainable improvement and development

2.3.1 Physical asset maturity evaluation model

Mark the scoring results of the r evaluators on the index U_{ij} as d_{ijk}, which can form an evaluation index matrix D:

$$D = \begin{pmatrix} d_{111} & d_{112} & \cdots & d_{11k} & \cdots & d_{11r} \\ d_{121} & d_{122} & \cdots & d_{12k} & \cdots & d_{12r} \\ d_{ij1} & d_{ij2} & \cdots & d_{ijk} & \cdots & d_{ijr} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ d_{421} & d_{422} & \cdots & d_{42k} & \cdots & d_{42r} \end{pmatrix} \tag{9}$$

Next, determine the whitening function of the gray number. The gray level of this article is divided into 5 levels. The corresponding whitening function includes the first gray type "initial level" with a gray number of $\otimes_1 \in [5, \infty)$; the second gray type "growth level" with a gray number of $\otimes_2 \in [0,4,8]$; the third gray type "standard level" ", the gray number is $\otimes_3 \in [0,3,6]$; the fourth gray category "mature level", the gray number is $\otimes_4 \in [0,2,4]$; the fifth gray category "excellent level", the gray number is $\otimes_5 \in [0,1,2]$. Their corresponding whitening functions as indicated in Table 2.

TABLE 2. WHITENING FUNCTION CALCULATION TABLE

Whitening function	Whitening function and value range

$f_1(d_{ijj})$	$d_{ijk}/5$	1	0
	$d_{ijk}\in[0,5]$	$d_{ijk}\in(5,\infty)$	$d_{ijk}\in(-\infty,0]$
$f_2(d_{ijj})$	$d_{ijk}/4$	2- $d_{ijk}/4$	0
	$d_{ijk}\in[0,4]$	$d_{ijk}\in[4,8]$	$d_{ijk}\notin[0,8]$
$f_3(d_{ijj})$	$d_{ijk}/3$	2- $d_{ijk}/3$	0
	$d_{ijk}\in[0,3]$	$d_{ijk}\in[3,6]$	$d_{ijk}\notin[0,6]$
$f_4(d_{ijj})$	$d_{ijk}/2$	2- $d_{ijk}/2$	0
	$d_{ijk}\in[0,2]$	$d_{ijk}\in[2,4]$	$d_{ijk}\notin[0,4]$
$f_5(d_{ijj})$	1	2- d_{ijk}	0
	$d_{ijk}\in[0,1]$	$d_{ijk}\in[1,2]$	$d_{ijk}\notin[0,2]$

Index U_{ij} belongs to the v (=1,2,3,4,5) gray evaluation coefficient of the gray evaluation category is X_{ijv}, and has $X_{ijv}=\sum_{k=1}^{r} f_v(d_{ijk})$; remember that the gray evaluation coefficient of the evaluation gray category that belongs to U_{ij} is X_{ij}, and has $X_{ij}=\sum_{v=1}^{5} f_v(d_{ijv})$, Then the gray evaluation weight r_{ijv} can be obtained according to $r_{ijv}=X_{ijv}/X_{ij}$, the evaluation index U_{ij} is recorded as r_{ij} for each gray evaluation weight vector, then there is $r_{ijv}=(r_{ij1},r_{ij2},r_{ij3},r_{ij4},r_{ij5})$, and the gray evaluation weight matrix can be recorded as:

$$R=\begin{pmatrix} R_1 \\ R_2 \\ \vdots \\ R_5 \end{pmatrix}=\begin{pmatrix} r_{111} & r_{112} & r_{113} & r_{114} & r_{115} \\ r_{121} & r_{122} & r_{123} & r_{124} & r_{125} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ r_{521} & r_{522} & r_{523} & r_{524} & r_{525} \end{pmatrix} \tag{10}$$

Record the evaluation vector of index U_i as A_i, and if there is $A_i=w_iR_i=(a_{i1},a_{i2},a_{i3},a_{i4},a_{i5})$, then $A=W\cdot R=(a_1,a_2,a_3,a_4,a_5)$, can be obtained. The maturity evaluation value of sub-index U_i is $U_i=A_i\times V^T$, and the total maturity evaluation value is $U=A\times V^T$.

3 EMPIRICAL ANALYSIS

3.1Comprehensive evaluation system of power grid physical assets

Starting from the scientific, hierarchical, systematic, and data availability requirements for the construction of the evaluation index system, the establishment of a "criteria layer-indicator layer" evaluation framework is shown in Table 3. The first-level indicators are asset structure, utilization efficiency, and health. Level and asset decommissioning, the included secondary indicators include a total of 6 cost-type indicators and 3 benefit-type indicators. Based on this, the secondary indicator sample data of 27 provinces in 2016 was collected. In view of the large amount of data, it is not shown in the article.

TABLE 3. INDEX SYSTEM DESCRIPTION

First level indicator	Secondary indicators	Indicator type	Index description
Asset structure	Asset success rate	Benefit type	Net asset value/Original value of asset value

	Percentage of new asset value	Cost type	The original value of the annual new assets/the original value of the annual asset value
	Proportion of long-duty assets	Cost type	The proportion of assets with more than 15 years of service age in total assets
Usage efficiency	Electricity sales per unit of assets	Benefit type	Annual electricity sales/annual original value of asset value
	Average load rate of substation	Benefit type	The ratio of average active power to economic transmission power
Health level	Defect rate of main transformer	Cost type	Number of main transformer defects/total number of main transformers
Asset decommissioning	Percentage of asset scrap value	Cost type	Annual asset scrap value/annual asset value
	Asset retirement rate	Cost type	Net value of scrapped assets/Original value of scrapped assets
	Unit asset retirement value	Cost type	Asset retirement value/asset retirement quantity

3.2 Index weight assignment

After obtaining the paired comparison matrices of 8 experts, the maximum eigenvalues and corresponding eigenvectors of each matrix can be calculated, and the consistency test can be performed accordingly. The results showed that the CR values of the matrix consistency test were all less than 0.1, and the test passed. The calculation results of subjective and objective weights and the revised comprehensive index weights are shown in Table 4.

TABLE 4. INDEX WEIGHT DATA

	Index 1	**Index 2**	**Index 3**	**Index 4**	**Index 5**	**Index 6**	**Index 7**	**Index 8**	**Index 9**
AHP	0.055	0.132	0.134	0.201	0.148	0.088	0.052	0.065	0.125
Entropy	0.155	0.180	0.094	0.105	0.126	0.069	0.141	0.198	0.040
Comprehensive	0.098	0.147	0.109	0.152	0.139	0.077	0.084	0.121	0.073

3.3 Evaluation and analysis of the management of physical assets in various provinces across the country

After weighting and standardizing the sample data, the positive and negative ideal solutions of each index are determined as shown in Table 5.

TABLE 5. POSITIVE AND NEGATIVE IDEAL SOLUTION CALCULATION RESULTS

	Positive ideal solution	**Negative ideal solution**
Asset success rate	0.0260	0.0150
Percentage of new asset value	0.0047	0.0574
Proportion of long-duty assets	0.0064	0.0509
Electricity sales per unit of assets	0.0720	0.0049
Average load rate of substation	0.0154	0.0404
Defect rate of main transformer	0	0.0610

Percentage of asset scrap value	0.0310	0.0020
Unit asset retirement value	0.0050	0.0560
Asset success rate	0.0035	0.0329

Calculate the Euclidean distance, gray correlation degree, and post progress between each secondary index and the positive and negative ideal solutions in turn, and then obtain the relative post progress ε of the physical asset management level of the inter-provincial power grid companies across the country as shown in Table 6. The calculation results of Euclidean distance and gray correlation in the table are the results after non-dimensional processing. The relative posting progress ε in the table is sorted, and the horizontal comparison results of the physical assets evaluation in 27 provinces (autonomous regions and municipalities) are obtained, as shown in Figure 1.

TABLE 6. RELATIVE POST PROGRESS CALCULATION RESULT

Province	**Euclidean distance L+**	**Euclidean distance L-**	**Grey relational degreeV+**	**Grey relational degreeV-**	**Closeness l+**	**Closeness l-**	**Relative closeness ε**
Anhui	0.761	0.751	0.939	0.788	0.845	0.775	0.522
Beijing	0.482	0.941	0.967	0.786	0.954	0.634	0.601
Fujian	0.580	0.893	1.000	0.737	0.947	0.659	0.590
Gansu	0.827	0.834	0.924	0.877	0.879	0.852	0.508
Hebei	0.866	0.703	0.832	0.930	0.767	0.898	0.461
Henan	0.762	0.786	0.871	0.905	0.828	0.833	0.498
Heilongjiang	0.578	0.892	0.979	0.753	0.935	0.665	0.584
Hubei	0.797	0.805	0.949	0.828	0.877	0.812	0.519
Hunan	0.642	0.866	0.973	0.765	0.919	0.703	0.566
Jilin	0.826	0.756	0.918	0.855	0.837	0.841	0.499
Jibei	0.576	1.000	0.942	0.840	0.971	0.708	0.578
Jiangsu	0.448	0.937	0.980	0.745	0.959	0.596	0.617
Jiangxi	0.779	0.726	0.876	0.827	0.801	0.803	0.499
Liaoning	0.595	0.816	0.878	0.830	0.847	0.713	0.543
Mengdong	0.849	0.767	0.920	0.858	0.844	0.853	0.497
Ningxia	0.968	0.657	0.846	0.923	0.752	0.946	0.443
Qinghai	0.711	0.815	0.942	0.805	0.879	0.758	0.537
Shandong	0.719	0.812	0.900	0.861	0.856	0.790	0.520
Shanxi	1.000	0.552	0.757	1.000	0.655	1.000	0.396
Shaanxi	0.609	0.854	0.930	0.800	0.892	0.705	0.559
Shanghai	0.428	0.996	0.987	0.747	0.992	0.588	0.628
Sichuan	0.764	0.741	0.926	0.802	0.833	0.783	0.516
Tianjin	0.469	0.967	0.985	0.764	0.976	0.617	0.613
Xizang	0.909	0.791	0.937	0.876	0.864	0.893	0.492
Xinjiang	0.965	0.709	0.883	0.912	0.796	0.939	0.459
Zhejiang	0.735	0.807	0.937	0.804	0.872	0.770	0.531
Chongqing	0.732	0.773	0.933	0.783	0.853	0.758	0.530

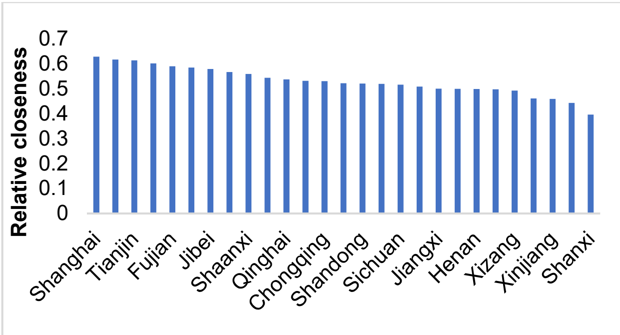

Figure 1 Provinces (autonomous regions, municipalities directly under the Central Government) horizontal comparison of physical assets evaluation histogram

It can be seen from the figure that the relative closeness of each region is mostly concentrated between 0.5-0.6, and the 27 provinces can be divided into 3 grades according to the ranking order: ① Grade I: Relative closeness $\varepsilon>0.6$. Including Shanghai, Jiangsu, Tianjin and Beijing, the level of physical asset management is relatively good. ② Grade II: Relative posting progress $0.5<\varepsilon<0.6$. Including Fujian, Heilongjiang, Hebei, Hunan, Shanxi, Liaoning, Qinghai, Zhejiang, Chongqing, Anhui, Shandong, Hubei, Sichuan and Gansu, the level of physical asset management is relatively high. ③ Grade III: Relative posting progress $0.4<\varepsilon<0.5$. Including Jiangxi, Jilin, Henan, Mengdong, Tibet, Hebei, Xinjiang, Ningxia and Shanxi, the level of physical asset management needs to be improved, and the evaluation results are relatively unsatisfactory. In order to better understand the internal working mechanism of the pros and cons of the 27 provinces ranking, the maturity of each indicator is measured.

3.4Evaluation of maturity of physical asset management in various provinces across the country

In order to save space, this section uses Beijing and Sichuan Province as examples to measure the maturity. The sample data of the two regions is shown in the left half of Table 7, and the right half is the scoring data reduced to a 5-point system. According to the aforementioned theoretical basis and the indicator data in the above table, the gray evaluation weight vectors of Beijing and Sichuan Province are calculated as $A=(r_{11}, r_{12}, r_{13}, r_{14}, r_{15}, r_{16}, r_{17}, r_{18}, r_{19})^T$ and $B=(r_{21}, r_{22}, r_{23}, r_{24}, r_{25}, r_{26}, r_{27}, r_{28}, r_{29})^T$.

$$A=\begin{pmatrix} 0.607 & 0.759 & 1.000 & 0.500 & 0 \\ 0.886 & 0.892 & 0.523 & 0.000 & 0 \\ 0.800 & 1.000 & 0.667 & 0.000 & 0 \\ 0.923 & 0.850 & 0.467 & 0.000 & 0 \\ 0.514 & 0.650 & 0.856 & 0.700 & 0 \\ 0.800 & 1.000 & 0.667 & 0.000 & 0 \\ 0.669 & 0.836 & 0.900 & 0.350 & 0 \\ 0.600 & 0.750 & 0.500 & 0.500 & 0 \\ 0.600 & 0.750 & 0.000 & 0.500 & 0 \end{pmatrix} \qquad B=\begin{pmatrix} 0.299 & 0.374 & 0.288 & 0.039 & 0 \\ 0.206 & 0.257 & 0.343 & 0.195 & 0 \\ 0.263 & 0.329 & 0.313 & 0.094 & 0 \\ 0.263 & 0.329 & 0.313 & 0.094 & 0 \\ 0.293 & 0.220 & 0.488 & 0.000 & 0 \\ 0.396 & 0.385 & 0.220 & 0.000 & 0 \\ 0.088 & 0.109 & 0.146 & 0.219 & 0.438 \\ 0.156 & 0.195 & 0.260 & 0.390 & 0 \\ 0.143 & 0.179 & 0.239 & 0.359 & 0.080 \end{pmatrix}$$

According to Table 4, the weight vector Q=(0.098, 0.147, 0.109, 0.152, 0.139, 0.077, 0.084, 0.121, 0.073) is obtained, and the comprehensive evaluation weight vector of Beijing and Sichuan Province is A'=Q·A, B'= Q·B, and then obtain the comprehensive evaluation weight vectors of the two asset structure, utilization efficiency, health level and asset retirement respectively:

A'1=(0.113, 0.127, 0.097, 0.017, 0)

A'2=(0.085, 0.106, 0.071, 0.030, 0)

A'3=(0.025, 0.010, 0, 0, 0)

A'4=(0.075, 0.083, 0.079, 0.040, 0)

B'1=(0.088, 0.110, 0.113, 0.043, 0)

B'2=(0.081, 0.081, 0.115, 0.014, 0)

B'3=(0.030, 0.030, 0.017, 0, 0)

B'4=(0.037, 0.046, 0.061, 0.092, 0.043)

According to the principle of maximum degree of subordination, Beijing's asset structure, utilization efficiency, health level, and asset retirement are at the "mature level", "mature level", "excellent level", and "mature level" respectively. The corresponding indicators in Sichuan are at the " Specification level", " Specification level", "excellent level", "growth level". In the same way, the maturity levels of the other provinces' first-level indicators are shown in Table 8.

TABLE 7. DATA OF BEIJING AND SICHUAN PROVINCE IN 2016

	Actual statistics		**Scoring data after reduction**	
	Beijing	**Sichuan Province**	**Beijing**	**Sichuan Province**
Asset success rate	0.455	0.057	3.035	3.803
Proportion of new assets	0.025	0.093	4.431	2.902
Proportion of long-duty assets	0.020	0.030	4.000	3.500
Unit asset sales	234869.777	93927.270	4.614	1.000
Average load rate of main network	0.340	0.520	2.569	1.749
Defect rate of main transformer	0.055	0.010	4.000	3.500
Percentage of asset scrap value	0.010	0.131	3.344	1.824
Unit asset retirement value	3.217	6.171	3.000	5.000

TABLE 8. MATURITY LEVEL OF EVALUATION INDICATORS IN EACH PROVINCE

Province	**Asset structure**	**usage efficiency**	**Health level**	**Asset decommissioning**	**Overall maturity evaluation**
Beijing	Mature	Mature	Excellent	Mature	Mature→Excellent

Tianjin	Mature	Excellent	Mature	Mature	Mature→Excellent
Hebei	Specification	Excellent	Mature	Excellent	Specification
Shanxi	Specification	Specification	Growth	Specification	Growth→Specification
Mengdong	Specification	Specification	Mature	Growth	Specification
Liaoning	Specification	Excellent	Specification	Mature	Specification→Mature
Jilin	Specification	Mature	Excellent	Growth	Specification→Mature
Heilongjiang	Mature	Mature	Excellent	Specification	Mature
Shanghai	Excellent	Excellent	Mature	Mature	Mature→Excellent
Jiangsu	Mature	Excellent	Mature	Specification	Mature→Excellent
Zhejiang	Mature	Mature	Mature	Specification	Mature
Anhui	Mature	Specification	Mature	Growth	Specification→Mature
Fujian	Mature	Mature	Specification	Mature	Mature
Jiangxi	Mature	Mature	Growth	Mature	Specification→Mature
Shandong	Mature	Mature	Mature	Mature	Mature
Henan	Specification	Mature	Mature	Growth	Specification
Hubei	Specification	Mature	Mature	Mature	Specification→Mature
Hunan	Mature	Mature	Mature	Mature	Mature
Chongqing	Specification	Mature	Excellent	Specification	Mature
Sichuan	Specification	Specification	Excellent	Growth	Specification→Mature
Shaanxi	Mature	Mature	Mature	Growth	Specification→Mature
Gansu	Specification	Mature	Mature	Specification	Specification→Mature
Qinghai	Mature	Specification	Mature	Mature	Specification→Mature
Ningxia	Specification	Specification	Growth	Growth	Growth→Specification
Xinjiang	Specification	Specification	Mature	Specification	Specification
Xizang	Growth	Mature	Mature	Initial	Specification
Jibei	Mature	Mature	Mature	Specification	Mature

According to the calculation results, the overall maturity of each province has reached the "standard level" and above. Five provinces have reached the “excellent level” in utilization efficiency and health level, and most of the province’s asset structure is at the “mature level” and the “standard level”, while the maturity of asset retirement indicators is relatively low, and 7 provinces are “growth”. Level", 1 province is still at the "initial level" and has a lot of room for improvement.

4 CONCLUSION AND OUTLOOK

This paper establishes an index system including asset structure, utilization efficiency, health level, and asset decommissioning. Based on a comprehensive ranking model, it ranks the level of physical asset management in 27 provinces, and introduces a maturity model to classify the maturity level of each secondary indicator. Carrying out calculations, the conclusions are as follows:

(1) Using objective statistical data to calculate the relative posting progress to obtain the inter-provincial ranking results, and then to explore the maturity level of the internal system indicators of each province. The empirical results prove that the model can obtain progressive evaluation results for the evaluation objects.

(2) The level of physical asset management in developed regions such as Shanghai, Jiangsu and Tianjin is relatively high. The central and western regions such as Xinjiang, Ningxia and Shanxi have a lot of room for improvement, but the relative differences in the management level between provinces are not obvious.

(3) The maturity of inter-provincial physical asset management is better, and the utilization efficiency and health level of multiple provinces have reached an excellent level. However, attention should be paid to the asset structure and asset decommissioning, and attention should be paid to the establishment of asset life-cycle management mechanisms and the establishment of a good Asset investment and retirement cycle.

Acknowledgement. Project Supported by Science and Technology Project of State Grid Corporation of China (Key Technologies and Asset Optimization Strategies of Power Grid Shooting Regulation)

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