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Evaluation Research on Development Level of Energy Internet

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ABSTRACT

Considering the process of energy development and utilization and based on the development objectives of low carbon, high efficiency and electrification, this paper selects key indicators from three aspects, i.e., energy supply, energy consumption and energy trading. On the basis of the established indicator system, the structural entropy and factor analysis optimization model is built to select and optimize the final indicators. The selected indicators can provide a theoretical research framework for the study of development level and the prediction of development trend of global energy internet.

Keywords— Energy & Power, Global Energy Internet, Structural Entropy Factor Analysis

I. INTRODUCTION

With the development of economy and technology, the demand for traditional energy is constantly expanding, and the fossil energy on which people depend is gradually entering a period of exhaustion. The energy problem affects. the sustainable development of society [1][2]. It is a long and complicated process to deal with the challenges of energy resources, environment and climate change, which must be solved by people around the world together. Under this background, the concept of "global energy internet" came into being [3]. In order to better promote the development of energy internet, it is necessary to scientifically and reasonably select the indicators to represent the development level of energy and power, so as to study the development rule of energy and power. The indicator of energy power development level is based on the process of energy development and utilization, and is finally selected through scientific analysis, preliminary selecting, adjustment and optimization according to the core contribution points of energy supply, energy consumption and energy trading. The indicators of energy and power development level will provide a framework for the study of the historical rule of energy and power development and provide theoretical support for the formulation of the future development strategy of the global energy internet based on the pre-measurement of energy and power development trend.

II. INDICATOR SELECTION ANGLE, PRINCIPLE AND PROCESS

2.1 Indicator Selection Angle

The development of global energy and electricity is a complicated process, involving many fields such as economy, society, environment and technology. In order to analyze abstract indicators in a quantitative way, it is necessary to consider the social and economic benefits generated in the process of energy transfer and conversion [5]. In combination with the development goal of the global energy internet, to study the sustainable, clean, efficient and flexible development level of energy development in the focus of energy supply; On the energy consumption side, it focuses on the core influencing factors of the consumption environment, the low-carbon level of consumption and the level of electrification development. The focus of energy trading is on the development level of global energy allocation. Finally, through these three aspects, the development level of supply and demand trading system of energy internet is studied.

2.2 Indicator Selection Process

In order to ensure the comprehensiveness, rationality and operability of the indicators of energy and power development level, it is necessary to specify the selection process of indicators. It mainly includes three processes: the primary election, optimization and determination, which is shown in fig. 1.

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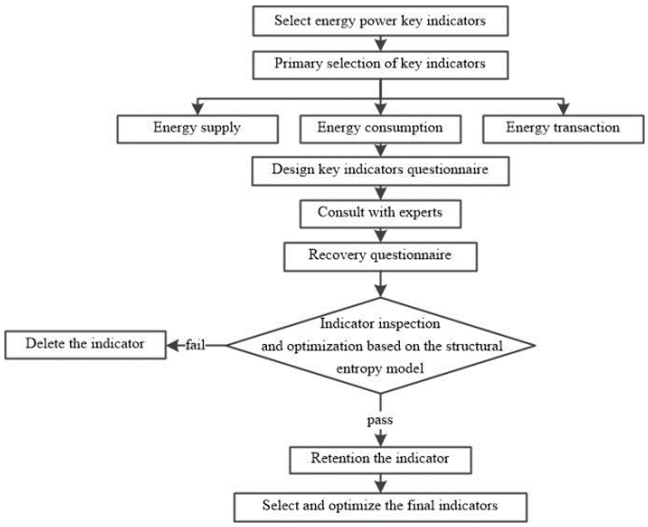

Figure 1: Flow chart of indicator selection

TABLE I
INDICATORS OF THE DEVELOPMENT LEVEL OF ENERGY SUPPLY

Indicator number	Evaluation dimension	Primary indicators
1	Resource endowment	Proven storage of fossil energy
2		Change trend of fossil energy storage-production ratio
3		Total power generation of renewable energy
4	Cleanliness	Energy production structure
5		Energy generation structure
6		Application scale of clean power generation technology
7	Efficient level	Energy generation efficiency
8		Energy efficiency
9		Power transmission loss
10	Diversification of supply	Proportion of Distributed Energy Generation
11		Proportion of centralized energy development and power generation
12		Net power generation of end users

III. PRIMARY SELECTION OF KEY INDICATORS

According to the basic process of energy and power development and utilization, the key indicators of energy supply, energy consumption and energy trading side development level were selected to fully reflect the level of energy and power development.

3.1 Energy Supply Level

With the depletion of fossil energy, people have put forward higher requirements for clean, efficient and diversified supply of energy utilization. Therefore, four evaluation dimensions are selected: clean level, resource endowment, high efficiency of conversion and transmission, and diversified supply methods. In order to ensure the comprehensiveness and rationality of the indicator, the development level of ecology, economy and technology should be considered comprehensively. The development level indicators on the energy supply side are shown in Table 1.

3.2 Energy consumption level

Energy consumption involves all fields of social life and all industries. In the " energy revolution", the energy consumption revolution aims to curb unreasonable consumption, optimize the industrial structure, develop low-carbon environmental protection industries and promote the electrification development of industries [3]. Therefore, it is important to examine the degree of electrification of energy consumption, the optimization of industrial structure and low-carbon water level [6] under the economic and social impetus to select the three evaluation dimensions of consumption environment, consumption structure and ecological sustainability. The primary indicators of energy consumption development level are shown in Table 2.

TABLE II
INITIAL INDICATORS OF THE DEVELOPMENT LEVEL OF ENERGY CONSUMPTION

Indicator number	Evaluation dimension	Primary indicators
13	Consumption environment	GDP growth rate
14		Population rate of increase
15		Total energy demand
16		Per capita energy consumption
17		Total electricity consumption
18	Consumption structure	Energy terminal consumption structure
19		The Structure of Fossil Energy Terminal Consumption Industry
20		Power consumption terminal consumption industrial structure
21		Energy consumption intensity of various industries
22	Ecological sustainability	Per capita CO2 emissions
23		Trend of global temperature change

3.3 Energy Transaction Level

Energy trading is an effective way to solve the problem of uneven distribution of energy in time and space and global energy shortage. Research on the development level of energy trading is mainly based on the scale of its development and the construction of transmission network. In terms of its development scale, it mainly examines its import and export trading volume and its proportion in total energy consumption. On the energy transmission network, considering that the energy source internet is the energy transmission configuration [4]. based on the interconnected power grid, the size of the power network determines the size of the energy internet to a certain extent. Therefore, the primary indicators for the development level of energy trading are shown in Table 3.

TABLE III
INITIAL INDICATORS OF THE DEVELOPMENT LEVEL OF ENERGY TRADING

Indicator number	Evaluation dimension	Primary indicators
24		Spatial distribution of energy supply and demand
25	Transaction size	Import and export volume of fossil energy
26		Electricity import and export volume
27		Energy reserves
28		Voltage class
29	Grid scale	Line length
30		Transmission capacity

IV. KEY INDICATORS OPTIMIZATION MODEL CONSTRUCTION

In this paper, the structural entropy factor analysis is used to analyze the rationality of the primary selection indicator of energy and power development, and the primary selection indicator is optimized according to the test results.

4.1 Establishment of structural entropy factor analysis *indicator optimization model [7]*

Structural entropy factor analysis combines Delphi method and factor analysis method, which collect expert opinions, to form a "typical ranking matrix" by analyzing system indicators and their interrelations, then denoise the typical ranking matrix by entropy principle, and adjust and optimize the indicators by factor analysis method, its steps are as follows.

Step 1 Design an indicator questionnaire and collect expert opinions. Experts scored the impact of each indicator on the development of energy and electricity to form a "typical ranking matrix".

Step 2 De-noising the original indicator, changing the "typical ranking matrix" into " structural entropy matrix" and reducing its uncertainty. Suppose there are *k* specialists who sort *n* indicators, and the sorting number forms a sorting matrix of $k \times n$, called " typical sorting matrix A ". The element in matrix A indicates the rank number of the “i-th expert” to the “j-th indicator”. The membership function of the qualitative and quantitative transformation of a typical sorting matrix is defined as

$$\chi^{(\mathrm{I})} = -\lambda \mathrm{P}_n(\mathrm{I}) \ln \mathrm{P}_n(\mathrm{I}) \tag{1}$$

Assuming

$$\mathrm{P}_n(\mathrm{I}) = \frac{m-\mathrm{I}}{m-1}, \lambda = \frac{1}{\ln(m-1)}$$

Substituting that into formula (1) and simplify the result

$$\chi^{\mathrm{I}} / \frac{m-\mathrm{I}}{m-1} - 1 = \mu(\mathrm{I}) \tag{2}$$

Then the structure entropy model is

$$\mu(\mathrm{I}) = -\frac{\ln(m-\mathrm{I})}{\ln(m-1)} \tag{3}$$

Where I is the qualitative ranking number of indicators given by experts, and μ is the variable defined on [0,1], $\mu(\mathrm{I})$is membership function of I.

Assuming $\mathrm{I} = \mathrm{q}+1, \mathrm{m} = \mathrm{q}+2$, q is the expert's maximum sequence number. Substitute that into formula (3) and the result is

$$\mu(q) = -\ln \frac{1}{q+1} \tag{4}$$

Substituting a_{ij} in " typical matrix" into formula (4) to obtain the structure entropy of a_{ij}.

That is $b_{ij}\left(b_{ij} = \mu(a_{ij})\right)$,
forming " structure entropy matrix" marked as.$\mathrm{B} = (b_{ij})_{k\times n}$

Step 3: Assuming *k* experts have same say about "individual indicators", calculate the average degree of experts' understanding of n indicators, which is marked as b_j

$$b_j = \frac{1}{k}\sum_{i=1}^{k} b_{ij} \tag{5}$$

Calculate the uncertainty of cognition of each indicator Q_j and the overall cognition of each indicator x_i And

$$Q_j = \left| \left\{ \begin{matrix} \left[max(b_{1j}, b_{2j}, \cdots b_{kj}) - b_j\right] \\ + \left[min(b_{1j}, b_{2j}, \cdots b_{kj}) - b_j\right] \end{matrix} \right\} /2 \right| \tag{6}$$

$$x_j = b_j(1-Q_j), x_j > 0 \tag{7}$$

Step 4: Performing factor analysis on the structure entropy matrix to form a factor load matrix. Based on the load of each indicator factor, the primary key indicator is adjusted and optimized. If the maximum factor load of the indicator is less than 0.04, it indicates that the indicator has little influence on the subordinate common factor and can be deleted. On the contrary, reserve the indicators.

4.2 Reduce uncertainty of primary selection indicators based on structural entropy

Design the " Expert Scoring Table" to ask energy Internet experts for the selection of indicators. According

to the degree of influence, it can be divided into five dimensions: " significant influence", " large influence", " average influence", " little influence" and " almost no influence", and the corresponding order is 1, 2, 3, 4 and 5 in turn

Summing up and sorting out the survey table to form a typical ranking matrix and testing the reliability of the survey results show that the Cronbach' s coefficient of the survey table is 0.903, much larger than 0.8, indicating that the survey table has high internal consistency and reliability.

According to equation (4), the typical ranking matrix is denoised and transformed into " structural entropy matrix" to reduce the uncertainty of the indicator by experts. On this basis, the expert's blind degree to the indicator is calculated by equation (5)~(7). According to the overall understanding of the level of development indicators to sort. According to the entropy theory, if the structural entropy value of the indicator is smaller, the more information the indicator reflects, the more representative it is.

From the calculation, experts believe that in the process of energy and electricity development, the fossil energy terminal consumption industrial structure, distributed energy development, centralized energy development and net power generation of end users rank the last four, and the overall awareness is obviously higher than other indicators, indicating that these four indicators are not representative enough and need further inspection.

4.3 Optimization of Key Primary Indicators Based on Factor Analysis

On the basis of standardization, factor analysis is carried out to further determine the rationality of the selection of energy and power development level indicators. Firstly, KMO sampling suitability test and Bartlett spherical test are carried out on the normalized " structure entropy matrix". The analysis results show that the ICMO of the data is 0.658 and Bartlett's spherical test value is 193.554, reaching significant water level$(\rho = 0 < 0.001)$, indicating that the data has a high efficiency and can be analyzed by factors. For this reason, the principal component analysis method is used to carry out “Varimax” variance orthogonal rotation on the primary indicators of energy supply development level.

From the results, after orthogonal rotation with maximum variance, eight common factors with eigenvalues greater than 1 can be extracted, and the overall contribution rate reaches 73.522 %. Secondly, factor load analysis is carried out. In the factor load matrix, when the indicator's maximum factor load is greater than 0.4, it indicates that the indicator has greater influence on the common factor. From the results, it can be seen that the maximum factor loads of indicators 9, 10, 11, 13, 20 and 27 are all less than 0.4, and the structural entropy value is too large, indicating that it is indeed unreasonable, so it is deleted.

The 21 indicators correspond to the 8 evaluation dimensions, namely the secondary indicators. Among them, the common factors 2, 6 and 8 correspond to the indicator of energy supply level; Public factors1, 4 and 5 correspond to energy consumption level indicators; Public factors 3 and 7 correspond to energy transaction level indicators. This verifies that the global energy and electricity development level can be evaluated from three aspects: energy supply, energy consumption and energy source trading.

On this basis, KMO sampling suitability test and Cronbach' s coefficient test are performed again on the adjusted indicators. The obtained KM0 is 0.704 and Cronbach' s coefficient is 0.947, which indicates that the adjusted data has higher reliability. Key indicators of energy and power development level are shown in Table 4.

TABLE IV
KEY INDICATORS OF THE DEVELOPMENT LEVEL OF ENERGY AND POWER

Level I	Level II	Level III
Energy supply	Resource endowme	Spatial distribution of energy supply and demand
		Change trend of fossil energy
	Cleanliness	Energy production structure
		Energy generation structure
		Energy generation efficiency
	Efficient level	
	Consumption environment	Energy efficiency
		GDP growth rate
		Energy demand growth rate
		Per capita energy consumption
Energy consumption		Total electricity consumption
	Consumption structure	Energy terminal consumption structure
		The Structure of Fossil Energy
		Terminal Consumption Industry Power consumption terminal
	Ecological sustainability	Per capita CO2 emissions
		Trend of global temperature change
Energy transaction	Ecological sustainability	Import and export volume of fossil energy
		Electricity import and export volume
	Ecological sustainability	Voltage class Transmission capacity

V. CONCLUSION

According to the selection characteristics, selection principles and selection angles of global energy and power development indicators, this paper conducts the primary selection of indicators from three aspects: energy supply, energy consumption and energy trading, and optimizes and adjusts the primary selection indicators by using the structural entropy factor analysis model, and tests the reliability. The test results show that the optimized indicator has higher confidence and is more reasonable

than the primary result. Finally, the key indicators of the global energy and power development show were established, and a theoretical framework for the study of energy and power development rule was established.

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