Original Research Article

Research on power system dual-cycle coupling evaluation based on entropy Weight -TOPSIS algorithm

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Abstract: With the development of the new energy industry, all walks of life have higher and higher requirements for the quality of the power grid, and the operation of the power system in different regions is different under the influence of many factors. In order to conduct a preliminary assessment of the operation of the power system by synthesizing various impact factors, the "Entropy-TOPSIS multi-objective evaluation model" was adopted to analyze and evaluate the relevant impact factors of six provinces in China (labeled U, V, W, X, Y, Z, respectively).The T-values of each province wereobtained, and preliminary conclusions were drawn as follows: The four provinces of U, W, Y and Z belong to the "good coordination", the province of X belongs to the "good coordination", and the province of V belongs to the "slight imbalance". However, due to the errors of the index systemand model theory, the accuracy of the results needs to be further improved. In the future, double-cycle coupling can be extended to multi-cycle coupling, and related problems can be further studied.

Keywords: Entropy weight-TOPSIS algorithm; Double-cycle coupling system; Multi-objective evaluation model; Power system evaluation

1. Introduction

In recent years, with the increase of electricity demand in various industries, the rapid development of micro-grid technology, UHV transmission technology and other technologies, the load-carrying capacity of the power grid is becoming heavier and heavier. Therefore, reasonable analysis and evaluation of the power grid operation in different regions is of great significance for local power distribution, comprehensive power dispatching, and power grid security monitoring.

"Entropy weight-TOPSIS method» and «multi-objective evaluation model» are widely used in mathematical modeling and engineering problems. For example, in literature[1], "multi-objective evaluation model" and "multi-objective track planning algorithm" are combined to obtain the optimal lane change trajectory of intelligent networked vehicles. In literature[2], the "entropy weight-TOPSIS algorithm» and «Analytic Hierarchy Process (AHP)» are combined to divide the green commercial indicator system into subjective and objective indicators, and a «5-level scoring system» is set up to obtain the perceptive degree level of each indicator, and comprehensively evaluate and optimize the use effect of green commercial buildings.

In this regard, six provinces in different regions of China were taken as research objects, an index system was constructed, and then divided into first-level indicators and second-level indicators in terms of power generation, distribution, transmission and electricity consumption, etc., corresponding data were collected, and "entropy-TOPSIS multi-objective evaluation model" was used to obtain data processing results. Finally, preliminary evaluation results were obtained through analysis and evaluation. On the basis of the preliminary evaluation, the "double-cycle coupling system model" is used to evaluate each object twice from the Angle of coupling degree, and finally a conclusion is drawn based on the results of the two evaluations.

2. Entropy weight -TOPSIS multi-objective evaluation model

The core algorithm of "entropy-TOPSIS multi-objective evaluation model" is "entropy-TOPSIS method». According to literature [3], "Entropy weight-TOPSIS method is a multi-attribute decision making method, which combines entropy weight method and TOPSIS method. The principle is that the entropy weight method is used to determine the weight of the attribute. The TOPSIS method is then used to rank and select decision options."

"Entropy weight-TOPSIS method" is suitable for solving multi-level and multi-objective evaluation, decision-making or optimization problems. According to literature[4] and literature[5], The main steps of this method include constructing index evaluation system, positive data normalization, positive matrix standardization, weight matrix, entropy, difference coefficient, weight of each index, weight matrix construction, ranking and analysis.

2.1. Build an index evaluation system

According to literature[6], the microgrid power system consists of a variety of devices and systems, mainly including distributed energy devices, energy storage devices, control systems, converters, power equipment and smart meters. Therefore, under the condition of "power system operation analysis and evaluation", the index system of this problem is constructed from four aspects of power generation, distribution, transmission and consumption .

First-level indicators(B): Generate electricity(B1),Power distribution(B2),Power transmission(B3) ,Electricity usage (B4).

Secondary indicators(C): Total annual power generation(C1),Annual thermal power generation(C2),Annual hydropower generation(C3),Annual wind power generation(C4),Annual photovoltaic power generation(C5),Proportion of total new energy generation (C6),Average cable service life(C7),Average service life of tower(C8),Average service life of transformer(C9),User size(C10),Transmission voltage(C11),Total length of transmission line(C12),Regional transmission line density(C13),Total annual electricity consumption(C14),Annual per capita electricity consumption(C15), Electric vehicle output(C16) ,The proportion of electric vehicles(C17).

When analyzing the advantageous location conditions of international urban transportation hubs, literature [7] constructs the index system of the inner circulation system and the outer circulation system with the help of the concept of «double circulation coupling system», divides the primary index of the inner circulation system into three factors of consumption, production and policy, and divides the primary index of the outer circulation system into two factors of investment and trade, and then subdivides their respective secondary indicators.

Therefore, in the study on the analysis and evaluation of the operation of the power system, a similar scheme is used. According to the components of the microgrid power system, the primary index of the inner circulation system (A1) is divided into two factors of power generation (B1) and distribution (B2), and the primary index of the outer circulation system (A2) is divided into two factors of power transmission (B3) and power consumption (B4). Then the secondary index is divided into 17 factors, such as annual total power generation (C1).

2.2. Data processing

$$\mathrm{A}=\begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1m} \\ a_{21} & a_{22} & \cdots & a_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nm} \end{bmatrix} \tag{1}$$

$$c_{ij}=\frac{a_{ij}-a_{\min[j]}}{a_{\max[j]}-a_{\min[j]}} \tag{2}$$

$$\mathrm{C}=\begin{bmatrix} c_{11} & c_{12} & \cdots & c_{1m} \\ c_{21} & c_{22} & \cdots & c_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ c_{n1} & c_{n2} & \cdots & c_{nm} \end{bmatrix} \tag{3}$$

$$\mathrm{Z}=\begin{bmatrix} z_{11} & z_{12} & \cdots & z_{1m} \\ z_{21} & z_{22} & \cdots & z_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ z_{n1} & z_{n2} & \cdots & z_{nm} \end{bmatrix} \tag{4}$$

$$z_{ij}=\frac{c_{ij}}{\sqrt{\sum_{i=1}^{n} c_{ij}^2}} \tag{5}$$

$$\mathrm{P}=\begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1m} \\ p_{21} & p_{22} & \cdots & p_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ p_{n1} & p_{n2} & \cdots & p_{nm} \end{bmatrix} \tag{6}$$

$$p_{ij}=\frac{z_{ij}}{\sum_{i=1}^{n} z_{ij}} \tag{7}$$

$$E_j=-\frac{1}{\ln n}\sum_{i=1}^{n} p_{ij}\ln p_{ij} \tag{8}$$

$$G_j=1-E_j \tag{9}$$

$$W_j=\frac{G_j}{\sum_{j=1}^{m} G_j} \tag{10}$$

$$\mathrm{S}=\begin{bmatrix} s_{11} & s_{12} & \cdots & s_{1m} \\ s_{21} & s_{22} & \cdots & s_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ s_{n1} & s_{n2} & \cdots & s_{nm} \end{bmatrix} \tag{11}$$

$$s_{ij}=z_{ij}\cdot W_j \tag{12}$$

$$\mathrm{D}=\begin{bmatrix} d_{11} & d_{12} & \cdots & d_{1m} \\ d_{21} & d_{22} & \cdots & d_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ d_{n1} & d_{n2} & \cdots & d_{nm} \end{bmatrix} \tag{13}$$

$$\mathrm{T}=\begin{pmatrix} t_1 \\ t_2 \\ \vdots \\ t_n \end{pmatrix} \tag{14}$$

$$t_i=\sum_{j=1}^{m} d_{ij} \tag{15}$$

Each research object corresponds to a ranking value, and the size of *n* ranking values is compared. The lower the ranking value, the better the operation of the power grid in this region. On the contrary, the higher the ranking value, the power grid operation in the region is relatively deficient.

3. Case investigation and analysis

3.1. Determine the research object

In the study on the analysis and evaluation of power system operation in each region, each research region is regarded as an ideal micro-grid power system. In order to comprehensively consider internal influencing factors (such as regional total power generation, proportion of total new energy power generation, average cable service life, user scale, etc.) and external influencing factors (such as transmission voltage, total length of regional transmission lines, total annual electricity consumption, annual per capita electricity consumption, etc.), the object rivers of the study are selected as 6 provinces in different regions of China. They are denoted as U, V, W, X, Y and Z respectively, and the specific study areas are: East China, South China, Central China, Northeast China, Southwest China and Northwest China, as shown in.

3.2. Double cycle analysis of data

According to databases such as "China Economic Information Network"[8], relevant data of 17 secondary indicators of 6 provinces in China in 2023 were obtained. Using MATLAB2022a programming, the "entropy weight -TOPSIS method" code is substituted, and multiple rounds of iterative operations are carried out according to the above 9 steps.

The T-values of each province of the double cycle are obtained respectively, in order to visually compare the absolute indicators of power operation in various provinces, a double-cycle T-value bar chart is drawn, as shown in Figure 1.

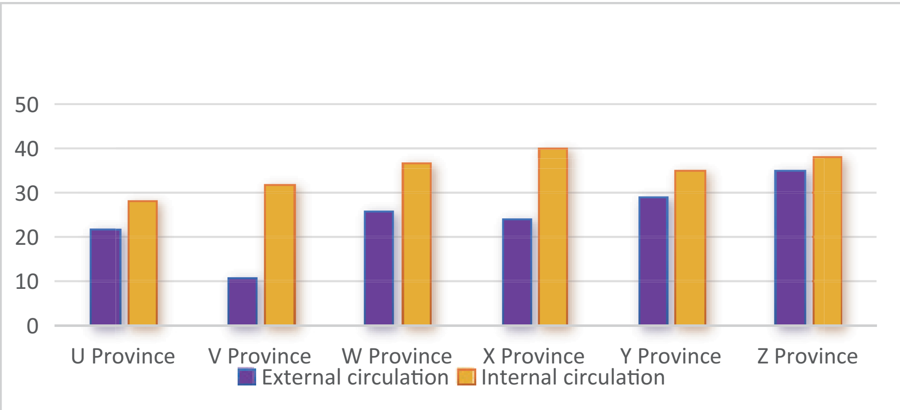

Figure 1. Double-cycle T-value histogram

In Figure 1, the operation of the power system in each province can be quantitatively obtained according to the absolute size comparison of T-value. In this figure, the shorter the column, the better the operation; On the contrary, the operation situation needs to be improved.

In order to compare the difference of internal and external power system operation in the same province qualitatively, the radar map is drawn.

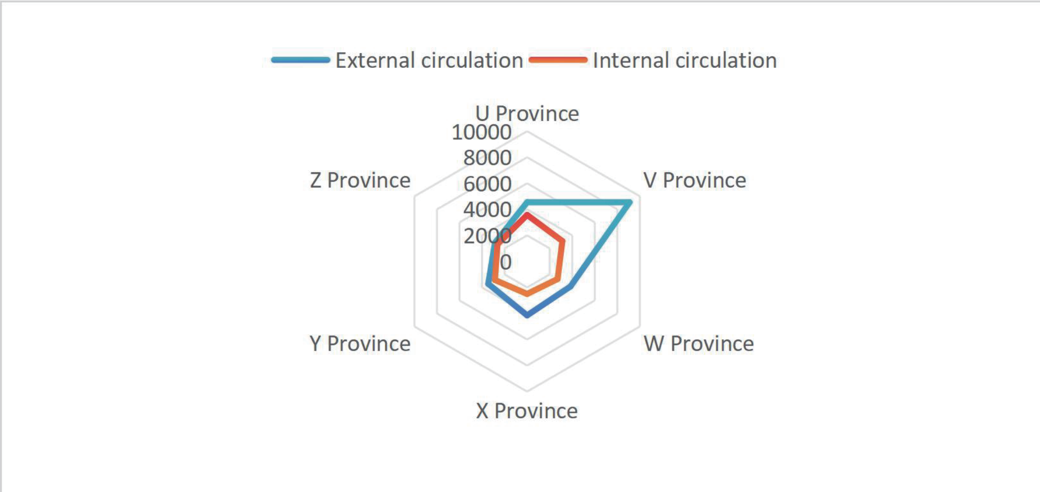

Figure 2. Double-cycle 100000/T value radar map

In Figure 2, according to the relative size of 100000/T value, the relative status of power system operation in various provinces is comprehensively compared by means of single-line multi-dimensional comparison method, dual-line single-dimensional comparison method, multi-line multi-dimensional comparison method, area comparison method and other methods:

In the same line, the higher the peak value of the radar map, the overall operation of the power system in the province is relatively better; On the contrary, the relative need to improve.

In the same six-deformation extension line, the greater the difference between the two lines, the greater the difference between the external and internal conditions of the power system operation in the province - these provinces are more suitable to give full play to the external advantages and make up for the relative deficiency of location conditions; On the contrary, the smaller the difference - these provinces are more suitable for fully coordinating internal and external linkage, strengthening links, and jointly promoting development.

In order to more intuitively reflect the overall internal differences of the six provinces, the internal and external circulation proportional area accumulation diagram is made, as shown in Figure3.

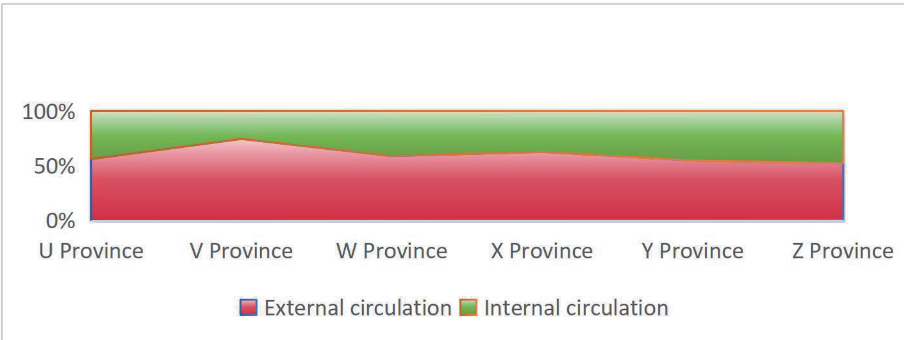

Figure 3. Proportional area accumulation diagram of internal and external circulation of power operation in each province

Based on the relevant data in Figure 2, Figure 3 can be used to obtain the relevant proportion of each province. It can be concluded that in the operation of the power system in most provinces, the proportion of external circulation is greater than that of internal circulation, and the advantage of external circulation in Province V is much greater than that of internal circulation.

3.3. Double-coupled analysis of data

The evaluation value of the outer cycle is u_1, the evaluation value of the inner cycle is u_2, the coefficient of the outer cycle is a, the coefficient of the inner cycle is b, the comprehensive evaluation index of the double cycle is t, the coupling degree is c, and the coordination degree is d, as shown in Figure 4.According to literature[7], the formula of dual coupling analysis is listed as follows:

$$t = a \cdot u_1 + b \cdot u_2 \tag{16}$$

$$c = 2\frac{\sqrt{u_1 \cdot u_2}}{u_1 + u_2} \tag{17}$$

$$d = \sqrt{t \cdot c} \tag{18}$$

In order to directly reflect the coupling relationship, the relevant data are drawn into a line chart, as shown in Figure 4.

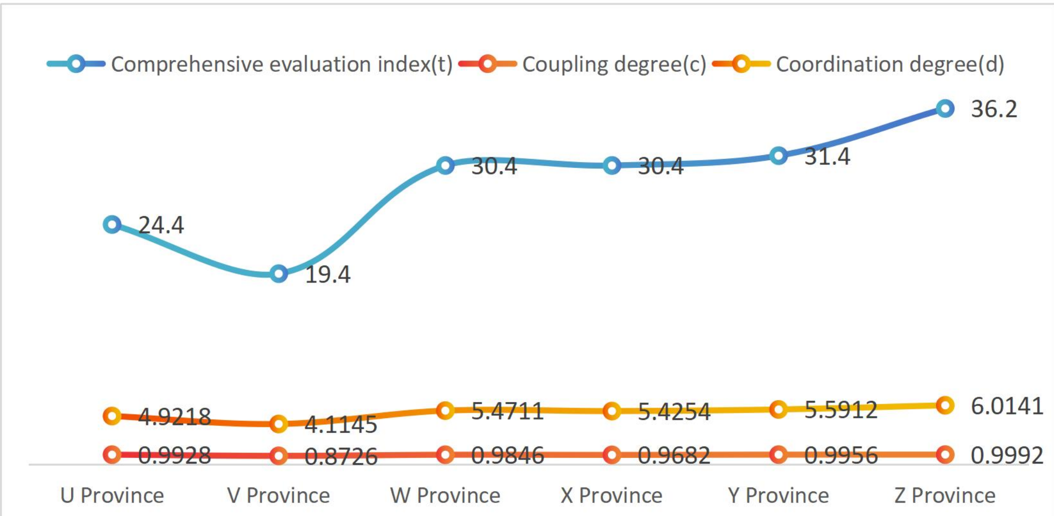

Figure 4. Line chart of variables of dual-cycle coupling relationship

Figure 4 shows the relationship between the dual-cycle coupling variables of each province in the traditional dual-coupling model (i.e., a=0.6,b=0.4). The lower the comprehensive evaluation index, the better the evaluation effect; On the contrary, it is relatively lacking.

Coupling degree and coordination degree reflect the close internal and external connection of power system operation in the region. Approximate results can be obtained according to relevant reference tables, as shown in Table 1.

According to other reference tables and the accuracy requirements of this number estimation, the coordination level hierarchy is constructed. According to the scale, the four provinces of U, W, Y and Z belong to the "good coordination", the province of X belongs to the "good coordination", and the province of V belongs to the "slight imbalance".

Table 1. Coupling coordination level level table.

Coordination level	Coordination degree
0.98~1	Quality coordination
0.96~0.98	Good coordination
0.94~0.96	Intermediate coordination
0.92~0.94	Primary coordination
0.90~0.92	Forced coordination
0.88~0.90	Borderline disorder
0.86~0.88	Mild disorder
0.84~0.86	Moderate disorder
0.82~0.84	Severe disorder
<0.82	Extreme disorder

4. Closing remarks

Aiming at the problem of “power grid operation in different provinces”, this paper adopts the “entropy weight-TOPSIS multi-objective evaluation model” to take 6 provinces in different regions of China as research objects, and finally obtains corresponding rankings.

According to the “entropy weight -TOPSIS method”, the power grid operation of six provinces was evaluated and the results were obtained. However, due to certain errors in the process of data acquisition, index system construction, algorithm operation and model building theory, the evaluation conclusion could not be completely consistent with the reality.

In addition to errors in data acquisition and index system, the “entropy weight-TOPSIS method” used in this study also has shortcomings such as being very sensitive to weights, poor correlation, limited scope of application of indicators, and difficult to deal with fuzzy information. Therefore, this method needs to be improved when studying various problems to make the evaluation model more optimized. To make research and experimental results more accurate.

For such problems, the method of “double-cycle coupling analysis” is proposed on the basis of “double-cycle coupling analysis”. In the future, this research method will be further studied to make a more accurate evaluation of the operation of the power system.

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