

Research on Evaluation Method of the Access of Power User Considering Efficiency and Fairness

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Abstract. Whether power users can access the power grid without any difference is an important evaluation standard for the development of the power grid. This paper proposes a set of power users accessing Grid evaluation methods considering efficiency and fairness by constructing an evaluation model with time dimension and spatial dimension. In terms of time dimension, the probability distribution and coefficient of variation of service efficiency indicators of data samples are used to evaluate the fairness of service efficiency. In essence, it is the evaluation of the fairness of intangible resource allocation such as time. In terms of spatial dimensions, samples are first placed in accordance with spatial regions. And the fairness of tangible resource allocation is evaluated by plotting the Lorentz curve and calculating the Gini coefficient before and after optimization. Finally, access data of a certain region in Guangdong province is selected as a sample for analysis. The results show that the proposed method is feasible and effective.

Keywords: Evaluation Method; Power User; Accessing Grid.

1. Introduction

At present, the research on the fairness of infrastructure mainly focuses on two aspects. One is applying new theories, new methods, and new tools to better achieve the fairness of infrastructure, that is, the optimization of fairness of infrastructure. Zhao (2015) presents the distribution concept of rolling planning, the optimization allocation method of global CO₂ emission right based on Gini coefficient method and the corresponding mathematical model [1]. Li (2017) [2] and Hou et al. (2014) [3] construct optimization allocation method of public resources basing on the unreasonable and unfair distribution of agricultural water and soil resources. The other aspect is to analyze the fairness of the public service process or results, that is, the evaluation of the fairness of infrastructure. Some scholars research the fairness of the exercise of power dispatching in electric power industry by using different economic methods and propose evaluation indicators and methods [4-5]. Liu et al. (2009) evaluate the ability of using public sports resources fairly and equitably for vulnerable groups in the UK, and suggest optimizing the allocation of public sports facilities in order to protect the rights of the vulnerable groups [6]. It can be seen that scholars in related fields have accumulated research output of the fairness of infrastructure. However, there are few researches which are studied from the two dimensions of time and space. It indicates a research gap about the fairness of the allocation of intangible resources, such as time and manpower, that is, the service efficiency. And These studies provide a useful reference for the evaluation of users accessing the grid, these methods can be introduced into the research in this area.

2. Lorentz Curve and Gini Coefficient

The Lorenz Curve indicates the functional relationship between the cumulative proportion of the low-income population x and the total income ratio of the group of people $f(x)$. It is first proposed by American statistician Max Lorenz in 1905 to describe the degree of unequal distribution of income (wealth), and it is a useful tool for determining the average degree of income distribution [5]. At the early stage, the Lorenz curve was used to compare and analyze the wealth inequality of a country in different eras or in different countries in the same era. The curve has been widely used as a convenient graphical method for summarizing income and wealth distribution information, and has gradually been applied to many fields such as land and medical care. The method of drawing is: the abscissa is

the cumulative percentage of the population, and the ordinate is the cumulative percentage of income (as shown in Figure 1) [7].

The Gini coefficient is proposed by the Italian geometry and statistician Gini based on the Lorenz curve. The Gini coefficient is a relative statistical indicator that measures the degree of income inequality in the region as a whole. It is regulated by the United Nations as one of the indicators of social and economic development. By definition, the formula for calculating the Gini coefficient G can be expressed as:

$$G = \frac{S_A}{S_A + S_B} = 1 - 2B \quad (1)$$

$$= 1 - \int_0^1 \left(\frac{2}{\mu} \int_0^x g^{-1}(u) du \right) dx$$

$$G = \frac{\Delta}{2\mu} = \frac{\sum_{i=1}^n \sum_{j=1}^n |y_i - y_j|}{2n^2 \cdot \mu} \quad (2)$$

Where S_A is the area between the AEDC and the ADC (the purple section in Fig.1); S_B is the area between the ADC and the Absolute Unequal Distribution Curve (AUDC) (the dotted shadow section in Fig.1). n is the number of samples, $|y_i - y_j|$ is the absolute value of the income difference corresponding to any pair of samples. Formula (2), also known as relative Gini coefficient calculation model, is commonly used to calculate Gini coefficient.

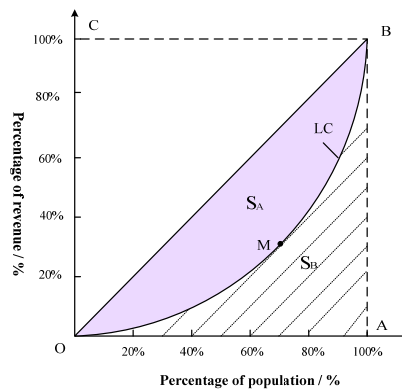


Fig.1 Lorenz curve

3. The Evaluation of Service Efficiency Fairness based on Time Dimension Consideration

3.1 Fairness of Service Efficiency

Efficiency is a term in the field of economics which refers to the ratio of input and output of resources [8]. Service efficiency refers to the ratio of service resource input to service effect output, and the effectiveness of service resource allocation. In order to obtain more revenue and improve customer experience, companies actively enhance service efficiency and service quality. Although profitability is not a major consideration for infrastructure, the improvement of service efficiency under limited resources is also important. Practically, however, it is a problem waiting to be solved that how to determine whether the service efficiency of infrastructure is fair or not.

3.2 Evaluation Model

An important indicator of service efficiency considerations is the completion time of a single service or the service completion rate per unit time. This paper considers the service efficiency from

the dimension of time, and then evaluates the fairness of service efficiency based on the probability distribution and coefficient of variation of the service efficiency indicators of all samples.

Assuming that the completion time of a public service is t_i , where i represents the sample number, thus the mean and standard deviation of the whole sample set can be calculated:

$$\delta = \sqrt{\sum_{i \in I} (t_i - \mu)^2 / N} \quad (3)$$

$$\mu = \frac{\sum_{i \in I} t_i}{N} \quad (4)$$

Where, N is the number of samples, I represent the sample set.

The completion time of each service can be regarded as an independent random event, because its value is influenced by some random factors. According to the central limit theorem, the mean value of variable t_i obeys the normal distribution of $N \sim (\mu, \delta^2/n)$ when the number of samples is large enough (generally $N > 30$) [9]. In this case, this paper evaluates the fairness of service efficiency based on the distribution probability of two indexes: The Coefficient of Variation (c_v) and the mean value (\bar{t}).

Index A: Coefficient of Variation (c_v)

c_v is a normalized measure of the discrete degree of probability distribution, it is defined as the ratio of standard deviation to mean value. c_v has no dimension, and its applicability is better than standard deviation. The mathematical expression of CV is:

$$c_v = \frac{\delta}{\mu} \quad (5)$$

Where, δ and μ represent the standard deviation and the mean of the samples, respectively.

Index B: The distribution probability of \bar{t}

Since \bar{t} obeys the normal distribution of $N \sim (\mu, \delta^2/n)$, the overall state of service efficiency can be elaborated by drawing the probability distribution curve and calculating the distribution parameters like μ and δ^2/n .

4. The Evaluation of Resource Allocation Fairness based on Spatial Dimension Considerations

4.1 Resource Allocation Fairness

In addition to the fairness of the service process, the fairness of resource allocation should be also considered. The fairness of the service process is concerned with the allocation of time resources, while the fairness of resource allocation focuses on the allocation of various tangible resources, indicating different evaluation angles and methods. This paper evaluates the fairness of tangible resource allocation based on the spatial dimension, that is, the rationality of resource allocation. The evaluation of this section will be conducted by delineating the Lorenz curve and calculating the Gini coefficient index, analyzing the rationality and fairness of regional resources in spatial dimension configuration, and analyzing the reasons for configuring the "short board".

4.2 Evaluation Model

Public service providers usually allocate resources according to the resource demand forecast value. The resource allocation scheme of the above method is used as initial scheme, the corresponding Gini coefficient is recorded as G_0 . Since it is inadequate to judge the fairness of public service subjects only through G_0 , the correction factors are introduced in this paper. Through the correlation analysis of the selected potential interference factors, the effective ones are identified as the correction factors. Each correction factor has an adjustment coefficient r to measure the influence degree, and the new Gini Coefficient G_1 is established:

$$G_1 = \frac{\sum_{i=1}^n \sum_{j=1}^n |y'_i - y'_j|}{2n^2 \cdot \mu'} \quad (6)$$

$$y' = y(r_1, r_2 \dots r_m) \quad (7)$$

Where, y' is resource allocation adjusted by correction factors, $y(r_1, r_2 \dots r_m)$ represents a multivariate regression function.

In this paper, resource allocation fairness degree Γ is used to evaluate the fairness of resource allocation in spatial dimension. According to the definition of Gini coefficient, the system fairness gets better when Γ tends to 1.

5. Case Analysis

5.1 Basic Data

The power industry is a basic industry of the national economy and a barometer reflecting the economic operation of the state. It is an important infrastructure. Considering the requirements of data integrity and accessibility, this paper selects the power user's grid access in a certain area of Guangdong Province as the analysis object of the example. In this research, the processing time of access is used as the evaluation index of service efficiency fairness, while the power expansion capacity of different regions is used as the evaluation index of resource allocation fairness. The data set includes: 1. The data of the processing time of access in 2017 is used as a sample set. The sample set contains a total of 712 data samples, eliminating 13 invalid data, and selecting 699 sample data for analysis, which is characterized as I_1 . 2. Setting the first 50% of the shorter service duration is the advanced level. The data of the advanced level in the region for 3 years is selected as the comparison sample set, which is characterized as I_2 . 3. There are 7 sub-areas under the jurisdiction of this area. A total number of 1,719 capacity expansion services of power facilities have been carried out in this area. The data of each capacity expansion service is one sample, and the sample set is characterized as I_3 . According to the division of 7 sub-areas, it can be further subdivided into $I_{3-1}, I_{3-2}, I_{3-3}, I_{3-4}, I_{3-5}, I_{3-6}, I_{3-7}$.

It is generally believed that the level of power system development is related to population, land resources and economic conditions. In this paper, correction factors a , b and c are set respectively to reflect the effect of the above factors. The specific data is shown in Table 1.

Table.1 Overview of Capacity Expansion and Correction Factors of Each Region

	Capacity MW	Population/ a 10^4	Land resources / b km^2	GDP/ c ¥ 100 million
Region1	48220	50.31	1693.60	178.71
Region 2	91850	50.53	1382.73	287.04
Region 3	65050	26.46	109.16	174.33
Region 4	70130	68.82	1656.94	341.57
Region 5	117115	74.30	321.97	685.55
Region 6	55525	95.07	2284.83	353.70
Region 7	99605	86.74	1354.71	597.62
Total	547495	452.23	7421.21	2618.52

Note: Capacity data comes from internal data of enterprises and is desensitized. Population, land resources and GDP data come from local statistical yearbook.

5.2 Evaluation and Analysis of Access to Infrastructure Efficiency Equity

Firstly, the comparative sample set I_2 is analyzed, and its probability distribution represents the advanced regions' performance. It is estimated that the mean and standard deviation of I_2 are 25.95 natural days and 5.32 natural days, respectively. According to the definition in Section 2.2, the sample of the processing time of extended services obeys normal distribution $N(25.95, 28.30)$, and the corresponding deviation coefficient θ is 0.025. The probability density function of the normal distribution is given in formula (8), the calculation result of c_{v2} equals 0.205 according to formula (5).

$$f(t) = \frac{1}{5.32\sqrt{2\pi}} \exp\left(-\frac{(t-25.95)^2}{56.60}\right) \tag{8}$$

Secondly, the fairness index is calculated according to formula (3)-(5), and the probability density function and probability distribution curve are contrastively analyzed through the results of comparison item shown in formula (8). The mean and standard deviation of sample set I_1 are 27.18 natural days and 11.21 natural days, respectively. The analysis shows that the normal distribution curve of the sample set I_1 in this paper is obviously flat compared with the results of the comparative sample set I_2 , which means higher sample dispersion. Through data analysis, it is found that the average service time of I_1 is 1.23 natural days longer and the c_v value is 2.1 times larger than the results of the comparative sample set I_2 representing the advanced level, which indicates that the service expansion level of the power industry in this year is not ideal, and the overall efficiency, fairness and consistency of service need to be improved.

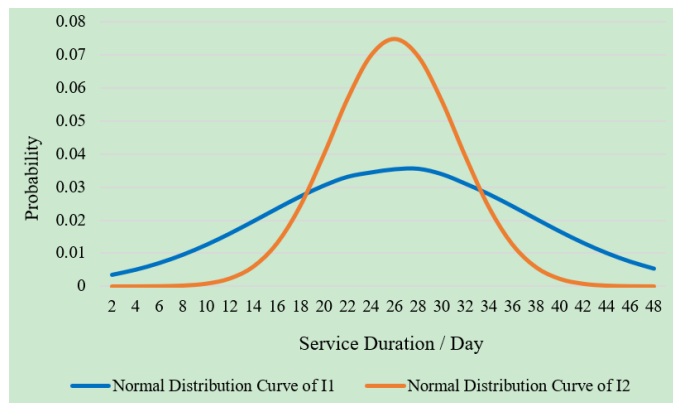


Fig.2 Comparative Analysis of Normal Distribution Curves

5.3 Evaluation and Analysis of Equity in Resource Allocation

This section focuses on analysing the rationality and fairness of regional resources allocation in spatial dimension according to the Lorentz curve and Gini coefficient index. The abscissa of Lorentz curve is area in spatial dimension, and the ordinate is allocated expansion capacity. The Lorentz curve of the initial configuration scheme (the relevant parameters are given in Tab.1) is shown in Figure 4. According to formula (1)-(2), $G_0=0.0919$, $\Gamma_0=1-G_0=0.9081$.

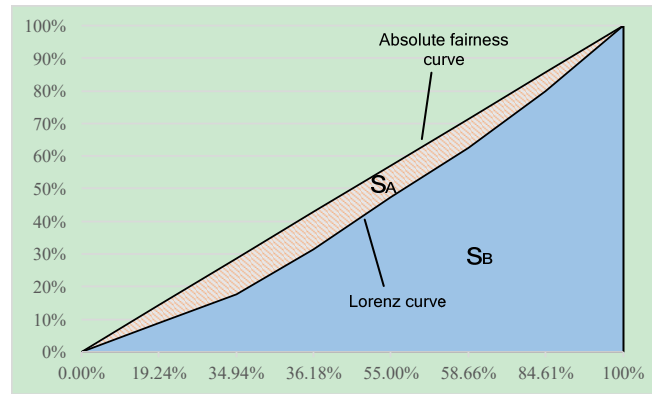


Fig.3 Lorenz Curve of Initial Configuration Program

Based on formula (7) - (8), the relationships between the correction factors a , b , c and capacity expansion are excavated through regression analysis conducted by SPSS Statistics. The analysis results (as shown in Tab.2) indicate that the significance test has not passed and the correction factors need to be adjusted.

Table.2 SPSS Regression Analysis Results (Coefficient Table)

Model	Non-standardized coefficient		Standardization coefficient	T	Significant
	B	Standard error			
1 (constant)	58282.510	16023.764		3.637	0.036
GDP(10^8 yuan)	197.165	99.097	1.546	1.990	0.141
Population (10^4 People)	-1046.318	1006.906	-0.969	-1.039	0.375
Area (km^2)	11.546	22.960	0.356	0.503	0.650

After verification, the expansion capacity of the region is only strongly correlated with GDP, which has been verified by the significance test (as shown in Tab.3). By using the non-standardized adjustment coefficient r , the function expression of the adjusted resource allocation is established:

$$y' = 106.5c + 38383 \quad (9)$$

Table.3 SPSS Regression Analysis Results after Eliminating Irrelevant Coefficients

Model	R	R ²	R ² (adjusted)	Standard slope error	
1	0.999	0.999	0.998	8077.324	
Model	Non-standardized coefficient		Standardization coefficient	T	Significant
	B	Standard error			
1(constan)	38383.909	13084.606		2.934	0.032
GDP(10^4 yuan)	106.475	31.424	0.835	3.388	0.019

Since I_2 represents the performance of advanced level, the regression results presented by formula (9) can be used as a basis for adjusting the allocation of resources. The adjusted configuration is shown in Tab.4.

Table.4 Capacity Expansion and Correction Factor of Each Area after Optimization

	Capacity MW	GDP/c ¥ 100 million
Region 1	57415	178.71
Region 2	68953	287.04
Region 3	56949	174.33
Region 4	74760	341.57
Region 5	111394	685.55
Region 6	76052	353.70
Region 7	102030	597.62

According to formula (1), $G_1=0.0677$, $F_1=1-G_1=0.9323$, and the corresponding Lorenz curve is shown in Figure 7. By comparing Figures 4 and 7, it can be seen that the two ends of Lorenz curve of the optimized configuration program are much closer to AEDC. We can also find that the area with the large change of expansion capacity after optimization is region 2 and region 6, while the area with small change is region 4, region 5 and region 7, which is consistent with what the Lorenz curve reflected. Although the regional area and expansion capacity have not passed the significance test, Lorenz curve still chooses regional area as abscissa, because both Gini coefficient and Lorenz curve focus on the state of spatial distribution rather than data correlation.

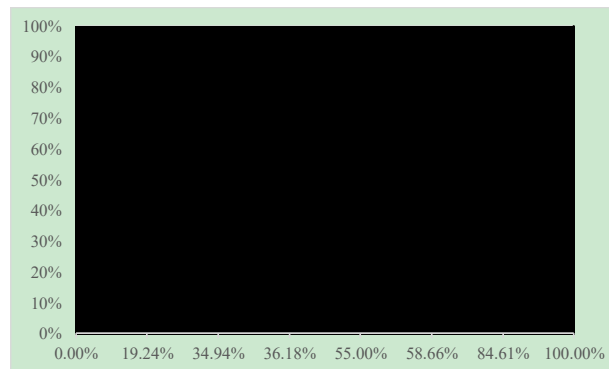


Fig.4 Lorenz Curve of Optimized Configuration Program

6. Conclusion

This paper proposes a set of evaluation methods for the fairness of power infrastructure. By constructing the evaluation model of time dimension and spatial dimension, the efficiency fairness of access to infrastructure and the fairness of resource allocation can be evaluated.

This paper selects the access of power user data of a certain region as a sample, and analyzes the two dimensions. The results show that: 1. The probability distribution curve of sample data can reflect the difference of the efficiency of access, that is, the probability of occurrence of different service durations is basically consistent with the case of the coefficient of variation cv ; 2. The Lorenz curve and the Gini coefficient can reflect the fairness of the allocation of resources in the spatial dimension; 3. When formulating the resource allocation plan, the correction factor through the significance test can be used as one of the factors of the optimization plan, which can promote the final fairness improvement. Due to the limitations of the author's level and length, there are still some issues to be studied. For example, the evaluation results of the two dimensions are relatively fragmented, and the quantitative indicators of efficiency fairness are too small.

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