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A Study on the Pricing Strategy of Jiangsu Province Residential Stepped Tariff Based on the Fuzzy Density Clustering Hierarchical Method

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Abstract. This paper proposes to introduce the pricing method for Jiangsu province of China residential stepped tariff. It integrates with power estimation method for household electrical appliances, the statistical analysis of monthly average household power consumption and the fuzzy density clustering stratified theory to determine the level of stepped tariff structure. And the application results in Jiangsu Province verify that the model is more fair, reasonable and effective than the unified tariff, customers reduce their power consumption notably.

Keywords: Stepped tariff, Levels of power consumption, Cost accounting, Elastic response

1. Introduction

Residential stepped tariff pricing means a segmented pricing mechanism in accordance with the electricity consumption level. The stepped tariff pricing policy encourages residents to conserve electricity power, especially for luxury using. On the other hand, taking into account the affordability of different income level, it can gradually reflect the reasonable costs of power supply and consumption, reducing tariff cross subsidies. The United States, Japan, India, South Korea, Egypt, Iran, the Philippines, Malaysia, Hong Kong, Taiwan have executed residential electricity ladder tariff price[1][2]. Since 2004, Zhejiang, Fujian, Sichuan, etc have also began to take out residential stepped tariff pricing policy, and have achieved certain effects [3][4]. In December 2011, National Development and Reform Commission (NDRC) of China gave out the protocol of opinions on residential stepped tariff pricing, and various provinces began to take actions.

The methods for residential stepped tariff pricing included the Ramsey law, coverage method, and optimization method based on the response of users[5]~[7]. Because the electricity consumptions are different largely among 12 months, the deterministic analysis of response of users cannot reflect seasonal factors and need to use actual dates to reduce deviations.

This paper introduces a residential stepped tariff pricing policy based on fuzzy density clustering stratified method, including pricing structure, price level, and the application results in Jiangsu Province prove the reasonable and suitable traits.

2. Basic principle

The specific principle for residential stepped tariff pricing policy for different income family, that should be different electrical policies, for example, low-income family should maintain the current welfare on electricity power use; Middle-income families should gradually reduce the electricity price subsidies; High-

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income family should compensate luxury electricity consumptions. The profile of residential electricity power consumption is shown as follows.

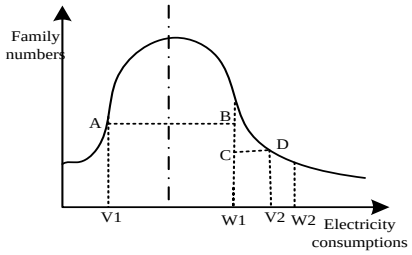

Fig.1 Power consumption profile

Given the hypothesis W1 and W2 are basic electricity consumption level, and for V1 customers, W1 far away from V1 would be encouraged because the reduced expenditure. For V2 customers, the closer the W1 is the more power consumptions would be saved. In accordance to the principle of incremental price, the customers would like to enjoy low price level as more as possible, in order to reduce costs. One goal is to establish model as follows [8].

$$\min(\tilde{Wi} = \int_0^{\infty} f(w)\,\tilde{w}_i\,dw) \qquad (1)$$

This means that the acreage composed by point A,B,V1,W1 is expected to be smallest, the same as acreage composed by point C,D W1,V2.

3. Grades of tariff pricing structure

The grades of stepped tariff should be determined in close contact with the local residents' living situation. In some areas, the difference between residents is small, so the grades could be less. Conversely, residents using quite different power should increase more grades to reflect the electricity consumption differences and the value of stepped tariff.

The RSR (Rank-sum ratio) theory is first proposed by Tian Feng-diao in 1998[4][9], which is applied to indicator identification and classification as a statistical analysis of classical parameter estimation and modern nonparametric statistics with their respective advantages. The principle of the theory is each indicators' parameter variances in consistent with each other in certain significant degree.

Thirteen different cities in Jiangsu Province with representative characters in geography, economics and culture are selected to collect residents with their electricity consumption information. The samples are calculated to obtain the dispersion modulus distribution and regression equation through RSR and the unit w probity.

$$\begin{cases} \overset{\Lambda}{RSR} = -0.38 + 0.176W \\ R^2 = 0.9631 \end{cases} \qquad (2)$$

The dispersion modulus of residents' electricity power consumption followed a normal distribution way as the modulus of determination is close to 1.

Considering the RSR principle, the tariff pricing policy should be divided into three grades and the results as follows.

Tab.1 The dispersion modulus of 13 cities samples

Item	grades	*RSR*	Variance
A	3	0.58、0.59、0.61、0.62	0.000334
B	4	0.79、0.81、0.83	0.000321
C	5	1.01、1.02、1.04	0.000301

4. Power level model of tariff pricing structure

The stepped tariff pricing structure should mainly reflect differences in household income, and the electricity consumption level ought to include the main distinctions between basic, normal and higher quality of life demands. So, it is possible to determine the scope of the stepped power consumption monthly by the power probability analysis and statistical estimation of household electrical equipments. Within the stepped power range, use the application of density clustering stratified method and choose the users' satisfaction responses as the goal to determine the stepped power consumption level. The specific computing model is described as follows.

4.1 Power estimation method

The probability distribution function of customer power consumption is to use Z as the random variable of power use to obtain the probability of the number of consumption less then z which is the average monthly power consumption mount, i.e.

$$F(z) = q\{Z \le z\} \qquad (3)$$

Using the data statistics of actual monthly power consumption of 28 million residents in Jiangsu province in 2011, the probability distribution curve of average monthly power consumption per family was shown in Figure 2.

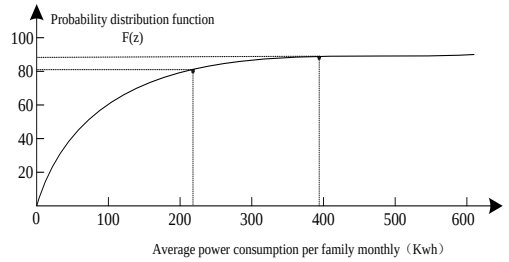

Fig 2 Probability distributions of monthly power consumption

The probability distribution function through regression analysis is:

$$F(z) = 10^{-14}z^5 - 5\times10^{-11}z^4 + 3\times10^{-8}z^3 - 2\times10^{-5}z^2 + 0.0079z - 0.145 \qquad (4)$$

Using the function, the average monthly power consumption was 218 kWh and 387 kWh in 80% and 95% probability respectively.

4.2 Statistical analysis of power consumption

Make survey of 5000 sample families in Jiangsu province with different income, to gain the amounts of power equipments, unit hour consumption and the time in use, and to estimate the average monthly power consumption.

Table.2 Sampled families average power consumption

Income	Low-	low	medium	high	High+
Monthly use	5-30	40-80	100-180	200-300	>400

4.3 Fuzzy density clustering stratified method

First make multivariate statistical analysis of the characteristics of the data to set different classification. Customer always hope to enjoy more low price to reduced electricity expenditures as possible, and hope the stepped level not close to needs. That means the less the number of customers close to the stepped level, the higher the customer satisfaction degree-the smallest point of customer distribution density[9]. Put the all household monthly electricity consumption samples to construct database, and use density clustering stratified method to successively classify those data, and the principle figure was as follows.

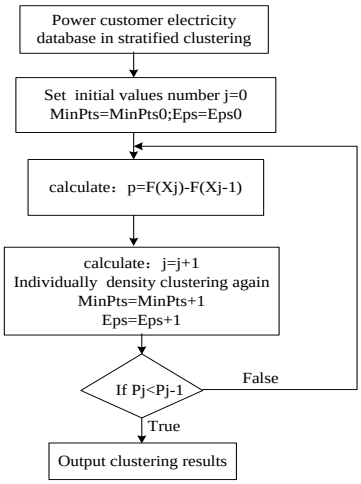

Fig.3 Fuzzy density clustering stratified diagram

Use C++ to write density clustering stratified program, the initial radius Eps and threshold MinPts were reset to 5 and 2 respectively, and through first and second density clustering stratified calculation, 16 particle size groups were gotten ,and the results were shown in table 3 below.

Tab.3 Distribution of power customers particle size groups

Particle size group	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-
Power kWh）	15	75	123	165	179	200	211	268
Particle size group	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-
Power（kWh）	310	430	480	535	550	632	670	700

By the preliminary merger of the particle size groups, the possible collection of the segmented power level were {75}、{123、179}、{211、268}、{310、430}、{535、670}.So the first level could take 225Kwh, the second 380, which covered 85%and 95% respectively.

Due to the characteristics of residential electricity consumption changed seasonally, the residential stepped tariff pricing policy should choose one year ,that is 12 monthly quota multiplied by 12 to get the basic level. Through investigation, analysis and calculation, integrated household electrical equipment estimated value, customer average monthly electricity consumption and fuzzy density clustering stratified results, the segmented power table is as follows:

Tab. 4 Residential stepped tariff base level in Jiangsu area

Tariff grades	I	II	III
Power level （kWh）	0-2760 （230*12）	2761-4800 （400*12）	4800 以上

5. Price level model of the tariff pricing structure

5.1 Power company electricity cost accounting

In China the power sale must follow "reasonable compensation cost" principle; therefore the total residential electricity consumption costs were how to equitably distribute among power terminal users. Based on classical long-term marginal cost pricing method dealing the equity problem, try to use a mixed long-term marginal cost pricing model for calculating integrated residential electricity costs, as figure4.

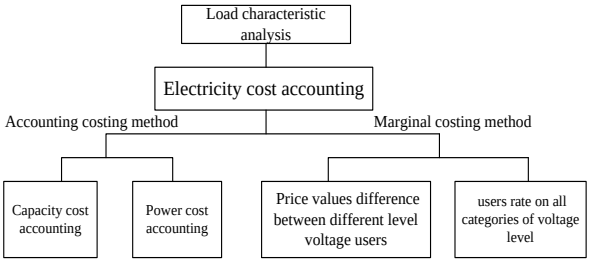

Fig.4 Power company electricity cost accounting method

The calculating model of the power costs for less than 1KV customer:

$$AC_{res} = \frac{\lambda}{1-\eta} \times AC_{sd} \bullet (\frac{\eta \bullet \tau_{res}}{\lambda_{res}} + \frac{(1-\eta)}{\lambda}) \qquad (5)$$

5.2 The user elastic response to the price

As the electricity price increases, residents will use alternatives to reduce electricity consumption. If W_i was class I residents ' average power user, here was logarithmic function curve of residential electricity demand and electricity price.

$$\ln W_i = D_i + \gamma_i \bullet \ln P_i \qquad (6)$$

This $\lambda_i = (dw/W)/(dp/P) = d\ln W / d\ln P$ is class I residents' price elastic modulus. Integrating customers' carrying capability factors, power price levels were developed as shown in Tab 5.

Tab.5 Tariff price and charge standard

Items	Grade I	Grade II	Grade III
Price change (yuan/Kwh)	unchanged	+0.05	+0.3
Power price (yuan /kWh)	0.5283	0.5783	0.8283

6. Model Assessment and Energy-saving effect

Jiangsu residential stepped tariff policy has applied since July 1, 2012. Through statistical analysis of 28 million households power use, high-end customers in power consumption reduce the monthly charge, while more turn to grade I. In addition, Jiangsu electric power company gives proper power subsidies for more population and disadvantaged families, reflecting the humanity care.

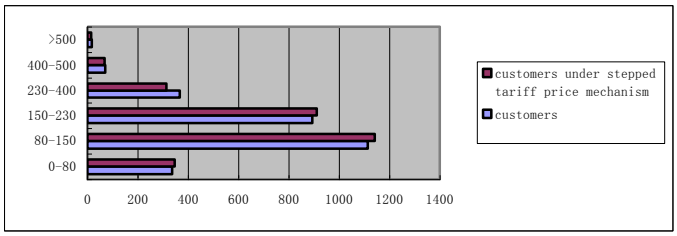

Fig.5 Diagram of customers' power change

7. Summaries

This paper researches on residential stepped tariff pricing policy based on fuzzy density clustering stratified method. The relationship between the household number and power consumption has great influences on the design of the tariff model. And the application results in Jiangsu Province verifies that the model is more fair, reasonable and effective than the unified tariff to encourage customers to reduces their power consumption and strive energy saving target.

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