CHEMICAL ENGINEERING TRANSACTIONS

VOL. 51, 2016

A publication of AIDIC

The Italian Association of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Tichun Wang, Hongyang Zhang, Lei Tian

ISBN 978-88-95608-43-3; **ISSN** 2283-9216

DOI: 10.3303/CET1651208

Renewable Electricity Pricing Mechanism Formation Mechanism Model Prediction

Qiang Cai[a], Li Le[*b]

[a] Sichuan Radio and TV University
[b] School of management and economics, university of electronic science and technology of china, Chengdu, China
qit0316@126.com

This paper mainly peak and valley electric charges price periods division and peak and valley electric charges determine optimized research established model peak and valley electric charges valley periods division and user response. First apply fuzzy math trapezoid membership function method to determine the load curve points at the possibility of peak, flat, valley period, providing a theoretical basis for the scientific division valley period. On this basis, load shifting, so that daily load curve of the system becomes more smooth for the purpose of considering the establishment of a user response peak and valley electric charges model and constraint condition set in a peak period pricing constraint that electricity peak period should not be higher than the cost of a small turbine to generate electricity, thereby reducing the small power generating units in the peak period of peak power generation, promote energy conservation.

1. Introduction

Grid load will generally change over time, peak load usually appears in the morning and in the evening, late at night load is low, forming a great valley difference. During peak hours, electricity demand, followed by power quality will decline, which may cause some accidents, in order to ensure safe operation of power blackouts sometimes required, resulting in unnecessary losses to production and life inconvenience, and in trough periods, the power supply exceeds demand, and the formation of the electrical socket. At this time, peak and valley electric charges pricing system for the load shifting provides a reasonable solution(Ackermann et al., 2000). Power companies can be determined according to the power grid load characteristic peak periods, at the peak of the price increase in trough price reduction to stimulate the user to adjust the power consumption behavior, by playing the role of price leverage to achieve peak load shifting purposes, ease of use peak electric tensions, tap peak electricity market, improve power social benefits. From an economic point of view peak and valley electric charges pricing system in line with the theory of marginal cost pricing is conducive to the rational allocation of resources(Aula et al., 2013).

From the energy point of view, the main objective peak and valley electric charges price policy are: to reduce peak demand for electricity segment, improve power system load rate, and improve the system load factor can reduce fuel consumption by thermal power, improve overall power system energy effectiveness. From the results of the survey, the peak and valley electric charges to promote and guide enterprises and residential users of electricity consciously adjust the time and manner of electricity, peak load shifting, does play a significant role.

But the current peak and valley electric charges price policy, there are some problems in the implementation process: First, the valley period’s division unscientific. Divided in some areas of the valley simply take the peak period is eight hours, without considering the actual load curve of the local situation, it is difficult to guide rational use of electricity users. The second is a smaller valley spreads. peak and valley electric charges abroad than in 4: 1 or more, up to 10: 1, China's general spread in the valley between two to three times, significantly lower(Ernst and Hackmann, 2013). Third, the implementation of peak and valley electric charges is in smaller range. At present, China mainly industrial users in popular valley in the price, to a lesser extent, commercial and residential customers though they take small proportion of the total electricity, but the absolute number is still large, and will become a new growth point of electricity consumption, You can consider the scope of their integration into the peak and valley electric charges. Fourth, peak and valley electric charges has been established, then no adjustment in a long time. Because after peak and valley electric charges making, power users will adjust their consumption patterns tariff policy, bringing new changes load curve, if peak and valley electric charges price policy does not make timely adjustments, turn the formation of new peaks and valleys, reach load shifting purposes(Hongesom et al., 2013).

For the peak and valley electric charges price policy play a better role, the need to optimize the peak and valley electric charges. Therefore, this article will address these issues peak and valley electric charges optimization studies, including for the period divided valley peak and valley electric charges theoretical basis and find the best valley periods division under development.

2. Peak-valley time-of-use tariff model based on DSM

Basic assumptions: (l) before and after the implementation of peak and valley electric charges daily consumption remained unchanged. According to the domestic implementation of demand-side management experience in the implementation of demand-side management, general consumption increased slightly or remained unchanged, so this is a reasonable assumption, (2) the average allocation was adjusted to a timeline hours of electricity. In practice, since the load characteristics of users, electricity and other factors, the user reaction is also different, so the transfer of power between different periods is different, but for ease of discussion, assume that the transfer of power according to the average distribution of the timeline here. (3) Here only consider the impact of the price of user needs, without considering other factors.

Although this hypothesis in practice a little rough, but it greatly simplifies the mathematical modeling difficulties, calculation errors resulting in a range of qualitative research is allowed, in line with the actual results. In order to facilitate the expression of the model, as will some of the parameters used in modeling listed.

2.1 Parameter explanation

(1) Division of peak-valley time period

The 24-hour day is divided peak, ordinary and valley periods. Since there are two peak periods, a valley period, so usually a maximum of three segments, namely:

$$T_f + T_p + T_g = 24 \tag{1}$$

In which: T_f is peak period, $T_f = T_f^1 + T_f^2$, T_f^1 is peak period 1, T_f^2 is peak period 2; T_p is ordinary period, $T_p = T_p^1 + T_p^2 + T_p^3$, T_p^1 is ordinary period 1, T_p^1 is ordinary period 2, T_p^1 is ordinary period 3; T_g is valley period.

(2) Electric charges Set up before the implementation of peak and valley electric charges average price of C_o, C_o is already known. After the implementation of peak and valley electric charges peak, flat and valley time price were C_f, C_p, C_g, the model can simulate the their values. For the usual price segment, because it represents the overall electricity tariff and a regional level, and the average price before the introduction of peak and valley electric charges C_0 has the same meaning, therefore, assuming C_o. To reduce the number of variables, $C_p = C_0$ level price segment taken as a constant, if not the implementation of the sales price or the annual average tariff peak and valley electric charges before, but also with the power of the Internet business settlement price, transmission price together.

(3)Electricity consumption

According to daily load curve, we can calculate the corresponding power consumption:

$$w_o = w_f + w_p + w_g \tag{2}$$

(4) Income of electricity supplier

Power supply side income refers to income from sales direction of the user, including the introduction and implementation of peak and valley electric charges income before income after peak and valley electric charges:

a) Before implementation of peak and valley electric charges, the income of power supplies is $M_0 = w_0 \mathrm{X} c_0$, b) After implementation of peak and valley electric charges, the income of power supplies is $M_1 = w_f \mathrm{X} c_f + w_p \mathrm{X} c$.

(5)Consumer spending

Consumer spending is the consumer in order to meet their own electricity needs and paid to the power company's electricity, its expenditure should be equal to the income side of the power supply, also includes the spending before and after implementation of peak and valley electric charges:

a) Before implementation of peak and valley electric charges, the consumer spending is $m_0 = M_0 = w_0 \mathrm{X} c_0$

b) After implementation of peak and valley electric charges, the consumer spending is $m_1 = M_1 = w_f \mathrm{X} c_f + w_p \mathrm{X} c_p + w_g \mathrm{X} c_g$

2.2 User response model

There are many factors affecting the user each time with a lot of electricity, the general relationship between electricity when the weather conditions, production status, shift, electricity, economic policy and other factors more closely. However, the actual controllability and DSM's point of view, the price is better control object, so there will be price as the user response model peak and valley electric charges price in a major consideration, and some other macro factors or temporary factors cannot be measured simplified. Given the degree of response to different users peak and valley electric charges price is not the same, if you are analyzed separately for each user, too complex, and may form a larger cumulative error, therefore, the focus here only for certain categories of poor valley important large users peak and valley electric charges Rate design, the following are the mathematical description of certain types of users(Chiandone, et al, 2013).

The reaction here is defined as a user: After the implementation of peak and valley electric charges pricing, users move from a period of high price to low price periods and electricity savings of electricity consumption and electricity consumption period with the original ratio(Fleeman et al, 2009). The reaction to their load characteristics of users, the way electricity, industry characteristics, and methods of dividing peak periods, but also with the price structure, electricity expenses and other related factors, discuss only reaction generated by users of the price that the user the reaction only to the difference between different periods related. Based on consumer psychology, the user has a minimum stimulation noticeable difference (difference thresholds), illustrates this difference within a range of values, the user is substantially no reaction or very little, to stimulate the same user also has a saturation value, more than this value, the user stimulus basically no further response. Therefore, assuming that the transfer rate and the peak, the peak level, peak and valley price difference is proportional to the time when the price difference between the different lower or higher than a predetermined value when the load transfer does not occur.

Assume L0(t) as the load of t before implementation of peak and valley electric charges:Δfg_{ij}, Δfp_{ij}, Δpg_{ij}, are respectively peak-valley price difference, peak-ordinary price difference and ordinary-valley price difference under program j, λfg_{ij}, λfp_{ij}, λfg_{ij} are respectively transition rate from peak load to valley load, transition rate from peak load to ordinary load and transition rate from ordinary load to valley load under program j, namely:

$$\lambda fg_{ij} = \begin{cases} 0 & 0 \le \Delta fg_{ij} < afg_{ij} \\ Kfg_{ij}\left(\Delta fg_{ij} - afg_{ij}\right) & afg_{ij} \le \Delta fg_{ij} < \lambda fg_{ij}^{\max} / Kfg_{ij} + afg_i j \\ \lambda fg_{ij}^{\max} & \Delta fg_{i\,j} \ge \lambda fg_{ij}^{\max} / Kfg_{ij} + afg_i j \end{cases} \tag{3}$$

2.3 Mathematical model of peak and valley electric charges

As a means of peak and valley electric charges pricing demand-side management, the need to meet the general requirements of demand-side management, while also achieve the target of its implementation and the conditions of some of the production activities must, therefore, must meet several model peak and valley electric charges Restrictions.

a) supply side profit: the implementation of peak and valley electric charges electricity sales revenue after the power supply side of the electricity plus investment and electricity cost savings should be greater than or equal implementation of peak and valley electric charges electricity sales revenue before the supply side, namely:

$$M_1 \ge M_0 - M_t \tag{4}$$

b) The user side benefit: After the implementation of peak and valley electric charges, electricity users should be spending less to implement peak and valley electric charges

Former user spending, namely:

$$M_0 \ge M_1 \tag{5}$$

c) Cost constraints: the low tariff period should be greater than the marginal cost of the system in the trough period:

$$c_g \ge c_e \tag{6}$$

d) In order to ensure that the system of electricity sales and ensure efficiency of large units, reducing the power of small thermal power generators during peak hours peak power, promote energy conservation and energy efficiency, this special setting a peak period pricing constraints, namely peak hours the price should be less than equal to the small power generating units of cost:

$$c_f \geq c_s \tag{7}$$

These are some of the development constraints peak and valley electric charges should be satisfied. So, what is the implementation of peak and valley electric charges expected to achieve the goal? Due to the implementation of the most intuitive and demand-side management objective is to load shifting load curve to Japan, so that daily load curve of the system becomes more smooth, thus facilitating the operation of the system and for this purpose through the implementation of peak and valley electric charges Japan load curve optimization, so here is a function to set the following objectives:

a) The maximum daily load curve of the load is reduced as much as possible, that is, to minimize the peak load daily load curve, which is typical of clipping.

$$\min_{f,c_f,c_p,c_g}\left[\max_{0\leq t\leq 24} L\left(f_t,c_f,c_p,c_g,t\right)\right] \tag{8}$$

b) The minimum daily load curve of the load as much as possible to increase that to maximize the load Valley daily load curve, which is typical of the valley.

$$\min_{f_i,c_f,c_p,c_g}\left[\max_{0\leq t\leq 24} L\left(f_i,c_f,c_p,c_g,t\right)\right] \tag{9}$$

c) The peak-valley difference of daily load curve should be as small as possible, namely to minimize the difference between peak daily load curve.

$$\min_{f_i,c_f,c_p,c_g}\left[\max_{0\leq t\leq 24} L\left(f_i,c_f,c_p,c_g,t\right)-\min_{0\leq i\leq 24} L\left(f_i,c_f,c_p,c_g,t\right)\right] \tag{10}$$

From the relationship between the objective function, there is a certain relationship between goal of a), b), c), so from the viewpoint of multi-objective optimization, the objective function can be selected from the three two objective functions We can achieve the same requirements. The following example is given which is a regional grid numerical example.

3. Calculation example

(1)Typical daily load curve, the typical daily load curve of the grid. In order to verify the effect of the model considered here several indicators related load curve:

a) Load rate= mean load/peak load×100%

b) Peak valley difference rate=(peak load-valley load)/peak load×100%

c) Peak valley= power consumption during peak period in one day / total power consumption in one day×100%

namely, the indicators of original load curve are:

Maximum load (P_{max})= 1.5560e+006kw

Minimum load (P_{min})= 0.9820e+o06kw

Load rate (P_{avg}/P_{max})= 83.48%

Peak-valley difference(P_{max}-P_{min})= 5.470e+005kw

Peak-valley difference rate(P_{max}-P_{min})/P_{max}) =36.89%

Peak occupation rate =46.13%

(2) Currently used peak and valley periods division

Taking all aspects of data analysis showed that peak and valley periods division of the grid currently used mainly researchers conducted a rough estimate was based on the characteristics of daily load curve and subjective experience of personnel divided as follows specific in hours:

Peak period: 7～11(P_e.1), 17～21(P_e. 2)

Ordinary period: 11～17(Ord. 1), 21～23(Ord. 2)

Valley period: 2～7 next day

(3) Electric charges analysis

The grid before the implementation of peak and valley electric charges average price of c_0 = 0.425 CNY / kwh) marginal cost valley period is C_e = 0.12 (CNY / kwh) small power generating units of the cost price of c_s, two main considerations part of the cost, a power generation cost of the fuel required, other fixed costs of small generating units.

(4) Surrender coefficient

Surrender coefficient is used to calculate the power to implement the investment and the cost of electricity after peak and valley electric charges savings from supply side, where it is defined as: the implementation of peak and valley electric charges power suppliers and electricity savings and investment by reducing the cost of electricity supply in the form of allowing users to benefit from the reduced price and the original price ratio as surrender coefficient.

(6) Optimization model

Objective function:

$$\min_{f,c_f,c_p,c_g}\left[\max_{0\le t\le 24} L\left(f_t,c_f,c_p,c_g,t\right)\right]$$

$$\min_{f,c_f,c_p,c_g}\left[\min_{0\le t\le 24} L\left(f_t,c_f,c_p,c_g,t\right)\right]$$

$$\min_{f_i,c_f,c_p,c_g}\left[\max_{0\le t\le 24} L\left(f_i,c_f,c_p,c_g,t\right)-\min_{0\le i\le 24} L\left(f_i,c_f,c_p,c_g,t\right)\right]$$

Constraint condition: $M_1 \geq M_0 - M_t$, $M_0 \geq M_1$, $C_g \geq C_e$, $C_f \geq C_s$

There are many multi-objective optimization methods are available for use, here the most simple and practical method to optimize the weighting factor weights through multiple spreadsheets to determine the right to the last three of the objective function in turn re-taken as 0.6,0.3,0.1. Theoretically, peak and valley electric charges fundamental purpose is to optimize load shifting, the load curve becomes smoother, and thus the operation of the system of benefits, therefore, the main consideration is the target load shifting, and its natural right value should account for a large proportion of the weight coefficients in the above-identified, which account for 90%, and therefore is more reasonable. The simulation calculation, the following valley period's division and peak and valley electric charges:

Table 1: The optimization results

indicators	The original load	The optimization results
The largest load	1.55	1.369
The minimum load	0.94	1.087
The peak valley difference	5.48	3.121
Adjacent moment load changes	1.54	1.025
The peak valley rate	36.24	22.343
Load rate	83.69	96.251
The peak rate	45.25	34.257

Peak period: 9～11(Pe. 1)，17～21(Pe. 2), 6 hours in total.

Ordinary period: 7～9(Ord. 1), 11～17(Ord. 2), 21～23(Ord. 3), 10 hours in total

Valley period: 23:00pm-7:00 next day, 8 hours in total

Electric charges: peak period 0.65(CNY/kwh)，valley period 0.14(CNY/kwh)

Peak and valley electric charges ratio: 4.64

Indicators obtained from peak and valley electric charges optimization model:

Maximum load (Pmax)=1.3973e+006kw

Minimum load (Pmin)=1.0852e+006kw

Load rate (Pavg/Pmax)=92.57%

Peak rate=34.73%

Peak-valley difference(Pmax-Pmin)=3，121e+ooskw

Peak-valley difference rate(Pmax-Pmin)/Pmax)=22.34%

Adjacent time load change time =1.0248e+006kw

Comparing the optimization results indicators to the original data, as shown in the table, we can see the advantages of optimized models: the peak load of load curve has been significantly reduced, the difference between peak and valley reduced for a certain degree, and peak-valley difference rate is reduced a lot, load factor has increased, the magnitude of change in adjacent time load has been effectively reduced peak accounted reduced a lot, but the downside is not much to improve the Valley load. In addition, energy saving and improve resource utilization efficiency requirements, the peak period should be as short as possible, so as to fully improve the efficiency of large units, so that a small generator set running time is reduced, making it unprofitable to ensure that the operational level of large units. The resulting model is a peak period of 6 hours, less than the original 8 hours, and the purpose of this article is consistent.

4. Conclusions

The article analyzes the peak and valley electric charges price periods division and peak and valley electric charges determine optimized research established model peak and valley electric charges valley periods division and user response. First apply fuzzy math trapezoid membership function method to determine the load curve points at the possibility of peak, flat, valley period, providing a theoretical basis for the scientific division valley period. On this basis, load shifting, so that daily load curve of the system becomes more smooth for the purpose of considering the establishment of a user response peak and valley electric charges model and constraint condition set in a peak period pricing constraint that electricity peak period should not be higher than the cost of a small turbine to generate electricity, thereby reducing the small power generating units in the peak period of peak power generation, promote energy conservation.

Reference

Aula B., Fadhil T., Lee S.C., 2013, Power fluctuation reduction methodology for the grid-connected renewable power systems, Proceedings of SPIE-The International Society for Optical Engineering, 14, 8688-8697, DOI: 10.1117/12.2012111.

Ackermann T., Andersson G., Söder L., 2000, Overview of government and market driven programs for the promotion of renewable power generation, Renewable Energy, 22, 1-3, DOI: 10.1016/S0960-1481(00)00015-X.

Chiandone M., Chiandone M., Milano F., 2013, Hierarchical voltage regulation of transmission systems with renewable power plants: An overview of the Italian case, 4th International Conference on Clean Electrical Power: Renewable Energy Resources Impact, 128-132, DOI: 10.1109/ICCEP.2013.6586978.

Ernst S., Hackmann R., 2013, A simulation based feasibility study to satisfy the energy demand of SME production sites by their own multi-source renewable power plants, Proceedings-2013 IEEE International Workshop on Intelligent Energy Systems ,34-39, DOI: 10.1109/IWIES.2013.6698558.

Fleeman J.A.,Gutman R.,Heyeck M., 2009, EHV AC and HVDC transmission working together to integrate renewable power, 2009 CIGRE/IEEE PES Joint Symposium Integration of Wide-Scale Renewable Resources into the Power Delivery System, 325-349, DOI: 10.1016/j.apenergy.2015.03.100.

Hongesom B., Komsan P., Thanadech, 2013, Evaluation of battery system for frequency control in microgrid system considering Power Ramp Rate of renewable power sources, Proceedings of the 6th IASTED Asian Conference on Power and Energy Systems, 42, 452-456, DOI: 10.2316/P.2013.800-134.