

# Research on Optimization of Commercial Electricity based on the Time-of-Use Price

—— Take Chongqing as an example

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**Abstract**—With the continuous development of the domestic economy, the demand for electricity continues to grow. In order to reduce the power consumption and the power supply pressure, Time-of-Use price (TOU) is more and more attention. And the nature of the commercial enterprise determines the majority of the electricity used in the peak and the general time, it can't enjoy the low price basically. If the commercial companies want to reduce electricity costs, it had to optimize their system of the power. In this paper, a supermarket in Chongqing as an example, the first analyzed the current situation and the cost of the supermarket reference to the Electricity price system in Chongqing, and then And then, according to E-7 TOU of California of the United States to estimated and analyzed the situation of electricity consumption in supermarket. And optimize the situation of electricity consumption on this basis, which can obtain the optimization strategy.

**Keywords**--*Time-of-Use; Commercial enterprise; Electric power; Power optimization; Scenario Analysis;*

## I. INTRODUCTION

With the continuous development of the domestic economy, the demand for electricity continues to grow. Electricity consumption of the whole nation total of 2662.4 billion kwh from January to June in 2015, up 1.3% from a year earlier.

From the view of industry, the first industrial consumed the electricity reached 44.1 billion kwh, an

increase of 0.9%; The second industry power consumption were 1924.2 billion kwh, down 0.5%; The third industrial electricity consumption were 339.7 billion kwh, an increase of 8.1%; From which we can see that the third industry electricity consumption has shown a trend of significant upward. In our country, most provinces still practiced traditional electricity sales model, but many foreign countries have promoted and improving TOU officially. In the research, TOU can effectively encourage users to transfer electricity load is reasonable, load shifting, reduce the rate of electricity load during peak hours, and reduce the supply pressure during peak periods, thereby improving the utilization efficiency of the system equipment capacity, and to ensure safe and stable operation of power grid.

Time-of-Use price refers to consider the changes in the load of power grid, could divide 24 hours into peak, flat, trough period, each period of the setting different price levels, respectively, to encourage customer reasonable arrangement of time, electricity utilization peak cutting and improve the utilization efficiency of electric power resource. At present, the domestic many scholars have studied. On the one hand, research mainly focused on the implementation of TOU price and the time sharing pricing, etc. Li Long (2015) through the analysis of TOU price, gives the calculation method of load time elastic size, based on the load time of elasticity to adjust TOU price model, and use the example simulating analysis. Then he confirms the TOU price peak shift and improves power grid load rate practical

and effective[1].Tan Zhongfu (2014) around the demand-side of electricity, such as price to give effect to the coal consumption of power generation side, sets up a joint optimization model of the TOU price and energy-saving power generation scheduling, and uses GAMS solution. Optimization results show that the optimization of TOU price will help to load distribution optimization, reduce difference between peak and valley load of electric power system and improve energy-saving scheduling of power generation side effect [2]. Zhuo Nana aiming at designing the period of TOU price division problem, based on the method of traditional fuzzy membership function in dividing peak-valley time period, considering the power user demand response, conducting TOU price assessment, and establishing the model of peak-valley time period partition by Clustering algorithm, obtains model in decision-making time plan[3].Based on introducing the approach of balance of the power peak and valley value period of segmentation, Wang Ningbo (2015) is on the basis of high load users' reactions to the TOU price, conducting model simulation, and combining the different time division method and the way of electricity pricing model solving method is given, and it is concluded that the division of the optimal time and TOU price pricing method [4].Gao Lin (2010) through the analysis and research of TOU price, consideration of the consumer psychology, electricity price theory and statistics theory, giving TOU price objective function based on the electric power enterprise target, and through the optimization of the model solution, it is concluded that the optimal TOU price pricing scheme[5]. Lian Zhenzhou (2014) through analyzing the characteristics of power load curve, applying the method of traditional fuzzy membership function in dividing peak-valley time period, and has the characteristics of the implementation scheme for dividing the time for adjustment, get four quarters of peak-valley time period classification scheme, and then weighted norm function method is used to obtain comprehensive scheme for dividing peak-valley time period throughout the year. Combining the example analysis shows that the scheme is more suitable for load distribution characteristic curve, can effectively motivate users demand response [6].

On the other hand, the research mainly focuses on the influence of TOU to the production of large industrial enterprises; Yu Na et al. (2014) to study the response of large industrial users under TOU. According to the power characteristics of industrial enterprises, the power decision model was set up in order to solve the optimal response strategy. and the effectiveness of the method is verified by case analysis[7]. Huang KunBiao (2008) in industrial enterprise electricity habits as the breakthrough point, through mathematical model to comparative analysis one shift, two shifts and three shifts of the cost of electricity in enterprise production basis TOU, and put

forward a scheme to adjust the class system, in order to achieve load shifting and reducing energy consumption purposes[8]. Zhao Hui et al. (2015) firstly established the optimal dispatch model of the electric load for the enterprises in the Time-of-Use price. And then using pattern search method, genetic algorithm and simplex method on Matlab platform to respective optimize electricity load dispatch of the enterprises, on this basis, draw the best practice of electricity load dispatch for the enterprise [9]. Wang Qiyang et al. (2008) according to the content of TOU price adjustment notice in Shandong Province to introduced and analyzed the local industrial electricity price, and adjust the time of the tire production based on the division of TOU pricing periods, to avoid production in peak demand periods, thereby reducing the cost of electricity[10]. Li Yang et al. (2001) has expounded TOU price structure, pricing strategies and large user corresponding econometric model using the theory of electricity price and relevant principles of economics, and analyzed the response of some large industrial users of Najing, and then discovered the main factors that affect the user response are production shift system, the proportion of electricity charge and the structure of electricity price, and it is proved that the reasonable price structure can get better load adjustment result[11].

To sum up, the current domestic research mainly focus on the implementation of TOU price, the division of the peak and valley period, and the impact of TOU on the production of large industrial enterprises, etc. And the research on the impact of TOU price in the field of commercial electricity consumption is less. Based on the above research, this paper studies the effect of the price of electricity on the commercial electricity cost, and analyzes the response behavior of the commercial enterprises and the electricity strategy under TOU price. And put forward electricity optimize suggestion of commercial enterprise.

## II. THE PRESENT SITUATION OF COMMERCIAL ELECTRICITY

At present, The part of the sales price in Chongqing is shown in Table I, Commercial electricity less than 1 kV which price is 0.8458 yuan/kw • h, the price of 1-10 kV commercial electricity is 0.8258 yuan / kw • h, the price of 35-110 kV commercial electricity is 0.8058 yuan / kw • h, 110 kV and above commercial electricity price of 0.7908 yuan / kw • h. In this paper, With the examples of a supermarket in Chongqing, which area is 1000m<sup>2</sup>-1500m<sup>2</sup> and the power supply is 380V generally, According to the current sales price list in Chongqing, its applicable price is 0.8458 yuan / kw • h.

TABLE I. THE PART OF THE SALES PRICE TABLE IN CHONGQING UNIT: YUAN/KWH

Classification of electricity	The electricity price			
	Less than 1 kV	1-10kV	35-110kV	110Kv and above
commercial and industrial electricity	0.8458	0.8258	0.8058	0.7908

The specific electrical power consumption of the supermarket as shown in Table 2, which vertical wind cabinet, freezer and cold storage is running 24 hours a day to work, and other electrical appliances worked with the time of the supermarket open. And according to the flow of people to determined the number of appliances running generally. According to the climate

characteristics of Chongqing, summer is generally hot and relatively long duration, and central air-conditioning use more. Due to winter climate is mild, the central air-conditioning use less; so the air conditioning was running in June, July, August and September generally.

TABLE II. ELECTRIC POWER CONSUMPTION OF THE SUPERMARKET

Electric appliance	Power consumption(kwh)	Quantity demanded	Electric appliance	Power consumption (kwh)	Quantity demanded
LED lamp	0.028	450	Central air-conditioning	4	12
Vertical wind cabinet	1.5	5m	Refrigerator	1.5	2.5m
Freezer	0.5	8	Cash register	0.2	6
Frozen cave	2.5	30m2	Other	1	--

Remarks: ①The output power of the central air conditioner is 5P;

②Other including the background server, and other low power consumption of electronics and other small appliances plus total.

The supermarket is open in 7: 30am-22: 00pm. The number of electrical appliances is different in different periods of time, and resulting in different power consumption of each period. LED lambs only open half the number in the day time (7:30-17:30), and the night time (22:00-17:30) will be fully open; Vertical wind cabinets, freezers and proposed works 24 hours a day;

Central air conditioning worked with the supermarket business hours in the four months of summer; Cash register, audio and other electrical equipment is also running with the supermarket business hours. Daily electricity consumption in the supermarket is shown in Table III.

TABLE III. SUPERMARKET DAILY POWER CONSUMPTION

Electricappliance	Power consumption (kwh)	Electric appliance	Power consumption (kwh)	Total except air conditioning (kwh)	Total (kwh)
LED lamp	119.7	Central air conditioning	696	411.1	1107.1
Vertical wind cabinet	72	Refrigerator	36		
Freezer	96	Cash register	17.4		
Frozen cave	60	Other	10		

The electricity costs of supermarket  $C=Q \cdot P$  (1)

Which Q represents supermarkets electricity, P represents commercial electricity price.

From this, we can obtain results that

➤ the average monthly cost of electricity of supermarket in the four months of summer is as follows:

➤  $C1=Q' \cdot P \cdot 30 = 1107.1 \cdot 0.8458 \cdot 30$

➤  $\approx 28091.56$  yuan

➤ Which Q 'represents supermarket daily consumption, P is price, 30 represents the number of days a month.

➤ The average monthly cost of electricity of supermarket in other months(No air conditioning) is as follows:

➤  $C2=Q' \cdot P \cdot 30 = 411.1 \cdot 0.8458 \cdot 30$

➤  $\approx 10431.25$  yuan

➤ From this. The annual cost of electricity of supermarket is as follows:

➤  $C=C1 \cdot 4 + C2 \cdot 8 \approx 195816.48$  yuan.

### III. COMMERCIAL ELECTRICITY COSTS UNDER THE E-7 TOU OF CALIFORNIA

Due to Chongqing has not TOU price management currently, this paper reference to California's TOU price to calculate and analyzes electricity consumption of supermarket. At present, the system of TOU price in California have been more perfect, It mainly has four

TOU price divided in different periods for people to choose ,which are E-6, E-7, E-9 and EV price. One of the most popular is the E-7 price, but also the most widely used. The period division of E-7 price as shown in Table IV.

TABLE IV. E-7 TIME-OF-USE PERIOD AND PRICE

Seasons	Time classification	Periods of Time	Electricity Price (yuan/kwh)
Summer (May-October)	Peak	12:00 noon-18:00 pm (Monday through Friday)	2.281
	Off-Peak	All Other Hours	0.706
Winter (November-April)	Peak	12:00 noon-18:00 pm (Monday through Friday)	0.920
	Off-Peak	All Other Hours	0.729

Remark: The conversion of electricity prices by the exchange rate of Bank of China: \$1 =6.3450 yuan.

If the electricity cost of the supermarket is calculated according to E-7 TOU price, we need to calculate the power consumption for each period, which has a positive correlation with the flow of people in the supermarket. According to the field survey found that

the peak period of the people in the supermarket are 8:30 am-12:00 noon, 16:30 pm-18:00 pm and 20:00 pm -21:00 pm. Table V is division of period based on the level of the peak flow of people to the supermarket, and calculate the power consumption of each period.

TABLE V. THE POWER CONSUMPTION OF EACH PERIOD (KW • H)

Period Electrical	7:30am- 8:30am	8:30am- 12:00 noon	12:00 noon- 16:30pm	16:30pm- 18:00pm	18:00pm- 20:00pm	20:00pm- 21:00pm	21:00pm- 22:00pm	22:00pm- 7:30am
LED lamp	6.3	22.05	28.35	12.6	25.2	12.6	12.6	0
Vertical wind cabinet	3	10.5	13.5	4.5	6	3	3	28.5
Freezer	4	14	18	6	8	4	4	38
Frozen cave	2.5	8.75	11.25	3.75	5	2.5	2.5	23.75
Central air conditioning	48	168	216	72	96	48	48	0
Refrigerator	1.5	5.25	6.75	2.25	3	1.5	1.5	14.25
Cash register	1.2	4.2	5.4	1.8	2.4	1.2	1.2	0
Other	1	2	1	2	1	2	1	0
Period power consumption	67.5	234.75	300.25	104.9	146.6	74.8	73.8	104.5

The formula of annual electricity cost under the E-7 TOU price as follows:

$$C = C_{\text{summer}} + C_{\text{winter}} \quad (2)$$

Setting a function:

$$f(x) = \begin{cases} 1, & 12 < t < 18 \\ 0, & \text{other} \end{cases}$$

(3)

Which t represent hours

The calculation model of supermarket electricity cost is as follows:

$$C = A_i \sum_{i=1}^{24} et * P1 + a_i \sum_{i=1}^{24} et * (P2 - P1) * f(x)$$

(4)

Which Ai said all days in the quarter, et said the power consumption of every hour, P1 represents the price of off-peak, P2 represents the price of peak, ai represents all days from Monday to Friday during the quarter.

In June to September, we need to calculate the electricity costs of the air conditioning, which a total of 122days and has 87 days from Monday to Friday, The other two months of summer (May and October) has 62 days which is 43 days from Monday to Friday. So summer electricity costs are calculated in two stages. In November to April next year a total of 181 days which is 129 days from Monday to Friday.

From this, we can obtain results that

$$C_{\text{summer}} = \left[ 122 * \sum_{i=1}^{24} et * 0.706 + 87 * \sum_{i=1}^{24} et(2.281 - 0.706) * f(x) \right] + \left[ 62 * \sum_{i=1}^{24} et * 0.706 + 43 * \sum_{i=1}^{24} et(2.281 - 0.706) * f(x) \right]$$

$$= 150872.4 + 25928.7$$

$$= 176801.1 \text{ yuan}$$

$$C_{\text{winter}} = 181 * \sum_{i=1}^{24} et * 0.729 + 129 * \sum_{i=1}^{24} et(0.920 - 0.729) * f(x)$$

=57130.69 yuan

Thus, we can obtain results that the annual cost of electricity of supermarket is as follows:

$$C = C_{\text{summer}} + C_{\text{winner}} = 176801.1 + 57130.69 = 233931.79 \text{ yuan}$$

To sum up, the costs of electricity under the TOU price is much higher than the costs under the conventional price. This is because the nature of the commercial enterprise determines the majority of the electricity used in the peak period. If commercial enterprises want to reduce electricity costs under the TOU, a better approach is to optimize their power system.

#### IV. OPTIMIZATION OF POWER UNDER THE E-7 TOU OF CALIFORNIA

For supermarkets, the most direct way to optimize the electricity is to control the operation of electrical appliances. The common appliances in the supermarket, Vertical wind cabinet, Freezer, Frozen cave and Refrigerator are works 24 hours a day. Therefore, the optimization of electricity control other electrical appliances will be more effective, and in other

appliances, the power consumption of LED lamps and Central air conditioning is the largest. During the day, the indoor lighting degree is better, we can turn a modest reduction in the number of LED lamp according to the level of peak flow of people. According to the field survey found that LED lamp can be closed to the maximum limit is 25% when the number of customer was less and ensuring lighting degrees in the supermarket. In the same way, Central air-conditioning can be closed to the maximum limit is 30%. Although it can reduce electricity costs but also making the shopping environment changes in supermarket, and impact on the customer's shopping experience.

This paper intends to set up three different scenarios for the control of the LED lamp in the time of the supermarket with less traffic, which is closed 25%, 15% and 5% respectively. The control of Central air conditioning is also set up three different scenarios, which are 30%, 20% and 10% respectively. Combination of different scenarios of two electrical appliances, and calculate the energy saving cost of each combination. As shown in Table VI.

TABLE VI. ENERGY SAVING RESULTS UNDER DIFFERENT SCENARIOS

LED lamp	central air conditioning	The daily energy saving with air conditioning runs (kwh)	The daily energy saving with no air conditioning (kwh)	Annual cost savings (yuan)
25%	30%	140.5	18.11	25751.01
	20%	99.7	18.11	19276.64
	10%	58.9	18.11	12803.12
15%	30%	133.27	10.87	23243.05
	20%	92.47	10.87	17425.37
	10%	51.67	10.87	10295.15
5%	30%	126.02	3.62	20692.98
	20%	85.22	3.62	14214.61
	10%	44.42	3.62	7747.71

The Table 6 shows that when LED lamp and central air-condition are closed to the greatest extent the year is the highest cost savings, on the contrary, when LED lamp and central air-condition are closed to the minimum extent, at this time of year is the lowest cost savings. But when we conduct the optimization and control of commonly used appliances of the supermarket, can not only consider the supermarket cost savings but also consider the supermarket shopping environment according to actual condition and customer shopping experience. Optimal solutions are obtained through comprehensive evaluation of them.

#### V. CONCLUSIONS

This paper based on the nature of the business enterprise industry and electricity characteristic analysis, studies the practice of TOU price mechanism of commercial enterprise power. And sets a supermarket in

Chongqing as an example, at first, referencing existing electricity price system in Chongqing to analyze the supermarket current energy consumption and cost; And then with reference to California's electricity consumption of supermarket TOU price conducts calculation analysis. And on this basis, the optimization analysis was carried out on the supermarket of the electricity supply and set up a variety of optimization, so as to draw a variety of different energy optimization strategies.

In the supermarket different power optimization scenario, when LED lamp and central air-conditioning can be closed to the greatest extent which LED lamp closed 25%, central air-conditioning closed 30%, annual cost savings of the supermarket can reach 25751.01 yuan, but at the same time, it is considered that this will influence the supermarket shopping environment and the customer shopping experience; When LED lamp and

central air-conditioning can be closed to the minimum extent in the optimized scenario, which LED lamp closed 5%, central air-conditioning closed 10%, annual cost savings of the supermarket is only 7747.71 yuan, in this scenario, though its supermarket shopping environment and customer shopping experience is good, but save the electricity cost too little for supermarket, electricity optimization without effective results. So, when we conduct power optimization, according to the business enterprise own actual situation to choose suitable strategy for their own electricity optimization, so as to save electricity cost, improve the economic benefits of enterprises.

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