A Load Management Strategy for Dropping the Power Energy Cost of Taiwanese Ceramics Industry

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Abstract

Taiwan Power Company (TPC) encounters the shortage of power supply due to deferring generation, transmission, and distribution construction. Therefore TPC prepares a beneficial electric rate policy such that the demand during peak time period of customer can be controlled decreasingly by executing the demand side management.

The aim of this research is to study the power cost reduction of the ceramics process for industrial customer and to relief the crisis of electric shortage during summer peak time period, through the load management measures. Yet this research is under the premise that the production and quality of ceramics will not be affected.

The first step of this research is to realize the characteristics of processing equipment and the power consumption of ceramics industry. Sampling theory is applied to select representative customers that are installed digital power meter to gather power consumption data. Then the measured data are compared to summarize the contents of load management measures so that an effective load management strategy can be proposed.

Results indicated that the local ceramics industry is highly willing to participate in the development of load management strategy. As the running time of ball mill is adjusted in tune with the beneficial rate of time of use (TOU), industry customer can save a certain amount of electric cost.

Finally, I suggest that the further research shall focus on the processing equipment characteristics and the power consumption of industry customer with large power demand. It is also desired that a feasible load management strategy is developed to assist the other industry customer to reduce power energy cost and to increase the competitive capability.

1. Introduction

1.1 Motivation

Owing to the rapid growth of industrial and commercial as well as the living standards as shown in the Table 1.1, the energy sales of Taiwan Power Company increase year by year that results in the insufficient capacity of reserved power supply as indicated in the Table 1.2. It is therefore that the power-rationing crisis could occur in the summer on-peak loading. This will definitely cause inconvenience for the industrial and commercial sectors and affect the civil life, and then the doubt and complaint toward the each procedure implemented by Taiwan Power Company. Thus it is urgent to alleviate the power-rationing pressure through load management strategies in reducing the power demand of on-peak hours. If the study on process, equipment and power consumption characteristics of the industries with large power consumption is carried out, the load method and potentiality on power saving or transfer of on-peak hours can be created. Along with the appropriate management or electric rate incentive package, it is expected efficiently reduce on-peak loading, and alleviate both power-rationing crisis and lower electricity cost. [1]

In tandem with the draft of electric rate incentive package, the load management strategy includes the beneficial rate in TOU rate and interruptible load procedure with respect to current electric rate and demand charge. Both customer and Power Company regard the rate as the production cost index. The Power Company sets up the reasonable rate structure based on the cost of supply side and the characteristics of demand side. By doing so, the rate of on-peak and off-peak hours is drawn up to reflect the power production cost in different power supply periods. While the load management option is applied to cope with the power consumption characteristics of customer in demand side. [2]

1.2 Papers Review

Before 1985, the reserved capacity of Taiwan Power Company could stably and sufficiently supply the power consumption, our government didn't lay much emphasis on the development of load management policy in power energy. It is therefore that the industries didn't pay much attention on their own load management procedures.

From 1985 to 1995, the rapid growth of economy as well as the prosperity of industry and commerce, which result in the increase of power consumption year by year. Besides the construction of nuclear power station and power transmission and distribution was conflict with the doubts of their safety and environmental pollution from the general public. Therefore the projects for power development were hampered by these difficulties and the power supply of on-peak hours was gradually insufficient. Thus our government emphasis on the load management of those industries with large power consumption in this duration. There are therefore many papers and relevant reports related to load management of power energy ready for reference. [1][2][3][4][5]

From 1995 to the present, the potentiality crisis of power-shortage does exist and will introduce complaint from the general public. In addition, our government lays great emphasis on the power consumption of high-tech industries. Consequently the target of power rationing falls on the less profitable conventional manufacturing sector. such as ceramics industry, etc. How to reduce the various productions cost is the survival means for the conventional manufacturing sector.

Generally the implementation of load management centers on price strategy. Assisted with the control of customer load and techniques in changing the power consumption ratio between on-peak and off-peak hours, the goal of price strategy can be achieved by applying various communication and control equipment. Yet the comprehensive and general rates in the price strategy such as demand charge, TOU rate are more complicated. Besides it can be applied to many customers and shall not be changed regularly and greatly. The power industries in the advanced countries adopt localization and selection policy. The target is set on those customers with large power consumption and high power cost. Along with price incentive, the results in the flexible use of power system & resource as well as load management can be attained. This is similar to the rate policy adopted by Taiwan Power Company.

The foreign load research places emphasis on load forecasting and demand side management mainly as the standing and policy of power supply industry [7]. It is rate to study power consumption characteristics for the individual industry and provide an effective load management measures in assisting the industry to save rate cost.

While the domestic power supply industry centers on the feasibility of interruptible load rate in which customers can participate. Besides the focus is put on the automatic load procedure to control the power consumption of on-peak hours. It rarely analyzes the process and the power consumption characteristics of each industry as well as provides them with the best measures to save power energy cost.

Based on the local and foreign experiences, this research therefore analyzes the process, equipment operation and power consumption characteristics of ceramics industry in Taiwan. From the demand side management, it is hoped that the effective load management strategies can be applied to decrease power energy cost [6][7] and boost the competitiveness eventually.

Table 1.1 The Investment Amount in Taiwan Area

Year	Amount	Public Sector	Public Enterprise	Private Sector
1993	14,896	4,268	2,488	8,140
1994	15,888	4,733	2,214	8,941
1995	17,506	4,970	2,284	10,252
1996	17,274	4,886	2,114	10,274
1997	18,954	4,950	1,982	12,022
1998	21,039	5,033	2,151	13,855
1999	21,247	5,207	2,412	13,629
2000	22,673	4,917	2,276	15,481

(NT$100Million)

Table 1.2 The Power Consumption Growth in Taiwan Area

Item	1980		1990		2000		1980-2000
	GWh	%	GWh	%	GWh	%	Growth Rate %
Total Consumption	39,821	100.00	82,647	100.0	171,950	100	7.59
Industry	26,736	67	49,171	59	97,450	57	6.7
House	7,157	18	16,394	20	34,543	20	8.2
Commercial	1,975	5	6,825	8	18,706	11	11.9
Agriculture & Transportation	1,041	3	2,045	2	3,350	2	6.0
Others	2,913	7	8,213	10	17,901	10	10

Source: Energy Commission Ministry of Economic Affairs

2. The Analysis of Ceramics Products and the Power Consumption Characteristics

2.1 The Analysis of Ceramics products

Ceramics, originated from Greek language Keramics, means the burnt stuff. In early stage it includes pottery and porcelain. The conventional or general ceramics is composed of three different kinds of raw materials, i.e. clay (formability), quartz (non-formability and rigidity) and feldspar (flux). Therefore it is defined as triaxial system ceramics.

The ceramics process is generally divided into: the formula of earthenware and glaze, slip casting and particle manufacturing, forming, and drying glazing and sintering.

The advancement of modern technology develops the compound ceramics excluding silicate salts. Its basic process still adopts powder preparation, forming and sintering. The connection study among ceramics microstructure, production techniques, properties and low cost production is major task for modern ceramics science. Besides the relation establishment of its qualitativeness, semi-quantitativeness and quantitativeness is included in this task. Due to its excellent property, the fine ceramics has served as the materials of function and engineering structure. While these ceramics are widely applied in the fields of information electronics, laser, nuclear reaction, high temperature, mechanics, aerospace as well as biology and becomes one of key links in the modern advanced technology. Only one factory in the ceramics industry produces printed resistor, the rest manufactures the conventional ceramics for building materials.

Taiwan conventional ceramics products divide into the following eight categories:

1. China: tableware or kitchenware such as cup and bowl.
2. Tile: indoor & outdoor paving tile for building, such as brick, quartz brick.
3. Sanitaryware Ceramics: sanitaryware made of ceramics such as water closet and urinals.
4. Esthetic Ceramics: antique reproduction and modern items, including antique reproduction vase.
5. Electrical Insulating Porcelain: various kinds of insulating porcelain lining.
6. Conventional Ceramics: crucible bowl and electric rod in the laboratory, acid-resist ball for the industry.
7. Refractory: the refractory poles and refractories for the kiln made of ceramics or metal smelting.
8. Ceramics Raw Materials: the raw materials used for ceramics industry and its processing industry.

2.2 The Production and Sale Analysis of Ceramics Industry

It is roughly about 700 ceramics makers in Taiwan. There are 29 manufactories of large energy consumption with major product tile.

The total production value of ceramics tile is 9502 square meter with totaling NT$14.08 billion, accounted for 0.24% of that of the manufacturing sector.

The main energy of ceramics industry is fuel, natural gas, and electricity with power consumption 3.73 kilowatt-hour, heat consumption of 23.64 x 10^3 kcal and heat/electricity ratio 7.38 for each square meter of tile as shown in table 2.1

Table 2.1 The Statistics of Unit Energy Consumption for Tile

Item	Production Quantity Unit	Unit power Consumption (kilowatt-hour)	Unit heat consumption x 10^3 kcal	Heat/electricity ratio	Energy cost (%)
Tile	Square meter	3.73	23.64	7.38	12.8

The total energy consumption of ceramics industry is 182,200-kiloliter oil, taking up 1.47% global of industry manufactory.

Table 2.2 shows the production quantity and value of Taiwan ceramics industry in recent years, which indicates the rapid decline of ceramics tile in terms of production, and production value since 1994.

Table 2.2 The Production Value of Taiwan Ceramics Industry in the latest Ten Years

Production & production value list of ceramics industry in the latest ten years		
Year	Ceramics tile	
	Production	Production Value
	(m^2)	NT$ Million
1987	59,002	9,130.1
1988	63,306	10,299.0

1989	69,644	13,205.8
1990	75,327	13,729.2
1991	79,217	13,681.4
1992	88,830	15,338.2
1993	116,888	212,633.0
1994	140,648	266,642.0
1995	131,704	220,143.0
1996	109,693	17,077.9
1997	95,022	14,086.5
Average	93,571	73,269.6

2.3 The Process and Characteristics Analysis on Ceramics Products

In the ceramics process, after the earthenware material and glaze are formulated, the slip casting is through milling process. It is the most common to apply ball mill in the slip casting. There are three key factors to affect the slip casting efficiency of ball mill. And different product in each plant has different requirements. Basically there's not much difference among them. Each plant keeps the running method of its ball mill confidential.

(1) The running speed of ball mill
(2) The quality of milling ball and slurry

The best condition for slurry quality is to fill 50% of ball mill capacity and add another 5% for milling. Upon selecting production batch, the factors shall be taken into consideration are: (a) The large batch serves mixing function not milling. It is therefore suggested that the slurry for milling should come in small batch. (b) It takes much longer time to mill large batch. (c) The density and viscosity of slurry. Based on experience and test, the results are as follows:

1. The viscosity scope is 550 ~ 1150cp by using the general porcelain ball.
2. The viscosity scope becomes 1200 ~ 2000cp after applying porcelain ball with high density.
3. The viscosity scope turns into 1000 ~ 2500cp through steel ball.

2.4 Ceramics Product and Process Characteristics analysis

The main products for the ceramics industry are brick, tile and quartz brick after the plant visit. Their production procedure from material milling to finished product is integrated. The process among each product is almost the same; the difference lies in the formula of raw material. Figure 2.1 illustrates the manufactured procedure of a certain tile factory. In the whole process, only the power energy is connected with the transmission motor, the following equipment uses non-electricity energy.

(1) Spray drying:—heavy oil as thermal source
(2) Drying furnace:—natural gas or the waste heat of kiln as thermal source
(3) Sintering furnace:—natural gas as thermal source

Function：

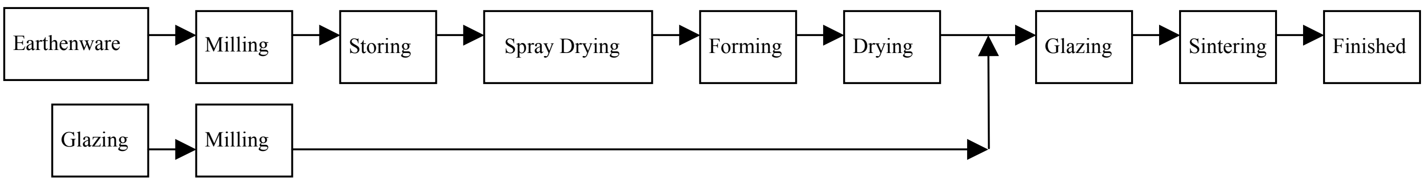


Figure 2.1 The Tile Production Procedure

Equipment Capacity：

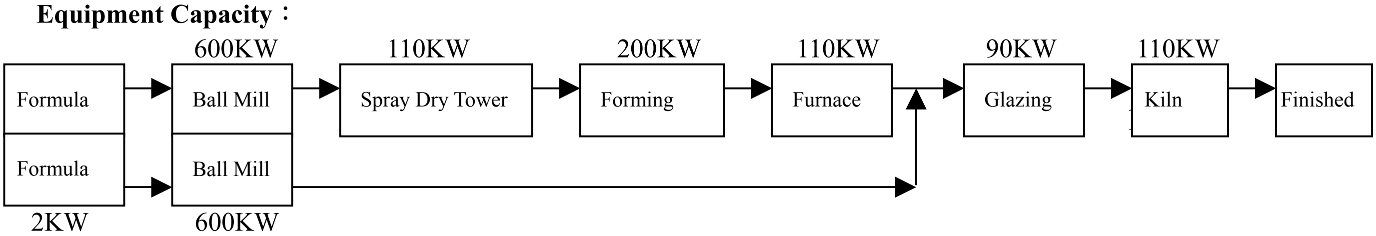
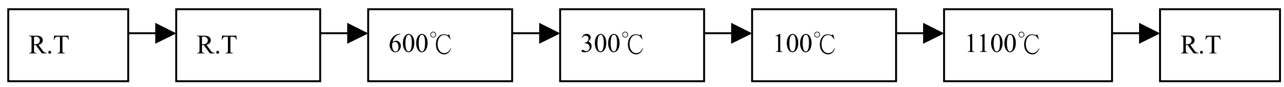


Figure 2.2 The Production Equipment and Power Capacity of Tile Maker

Working Temperature：



R.T: Room Temperature

Figure 2.3 The Temperature Distribution of Tile Production Process

Table 2.3 indicates the whole process and three kinds of energy consumption in one single day. While table 2.4 shows the cost and ratio of three kinds of energy. From the data, the natural gas cost is higher than that of electricity by three times. Both cost of electricity and fuel are almost the same. Unless the production changes of production generates the energy consumption change of fuel and natural gas will change. It is therefore assumed that these two energy cost are fixed. However the electricity cost depends on the different rates of on-peak and off-peak hours. As a consequence, the concept of TOU rate can reduce the electricity expenditure.

Table 2.3 The Consumption Comparison of Three Kinds of Energy in the Tile Process

Energy	Electricity (Kilowatt-hour)	Fuel (liter)	Natural gas (Cubic meter)
Consumption	6500/5745	2123	2830

Table 2.4 The Cost Comparison of Three Kinds of Energy in the Tile Process

Energy	Electricity	Fuel	Natural gas
Amount (NT$)/ratio	10578/20	9000/17	33397/63

From figure 2.2, it is clearly depicted that the power consumption of ball mill for earthenware material is the largest. The milling cycle of a ball mill is one hour of feeding, 13 ~ 16 hours of milling and half hour of unloading. After milling the slurry can be stored in the sink and the ball mill is not classified as continuous production type. It can be individually stopped in line with the load management of the interruptible load rate and TOU rate.

For the milling time of 15 hours at present the first ball mill starts feeding at 8:00 A.M., mills at around 10:00 A.M. and will stop at 1:00 A.M. of next day. While the second ball mill starts feeding at 10:00 A.M., mills at 12:00 P.M. and will stop at 3:00 A.M. of next day. These operations can be expressed in figure 2.4.

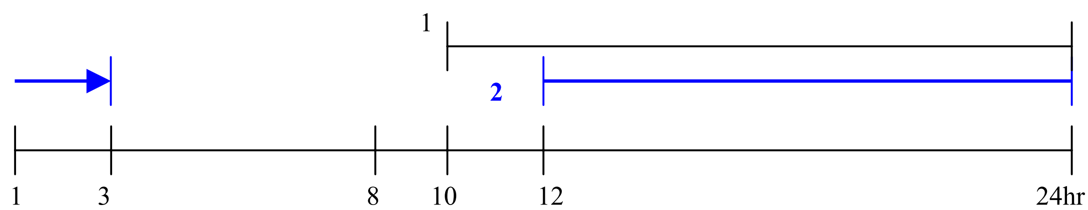


Figure 2.4 The Running Characteristics Figure of Ball Mill

From the above description figure, the 12 and half hours of running time for the first ball mill are within on-peak hours, only two and half hours fall in the off-peak hours. While the 10 and half hours of running time for the second ball mill are within on-peak hours, only 4 and half hours fall in the off-peak hours. Based on the rate ratio of on-peak and off-peak hours and the rate table of Taiwan Power Company, a kilowatt-hour of energy rate for on-peak & off-peak hours is NT$1.95 and NT$0.76 separately, i.e. the on-peak hours rate is 2.6 times of off-peak hours rate. For example by the power consumption of a 600kw ball mill, the rate of on-peak & off-peak hours in one day is NT$1,192.5 and NT$375 respectively, i.e. the on-peak hours rate is higher than the off-peak hours rate by 3.2 times. The difference will be considerable after year-after-year running.

If the running time of ball mill can be adjusted to fully use the 9 hours of off-peak electricity. The customer can save a large amount of electric fee. Meanwhile Taiwan Power Company can reduce power supply capacity in the on-peak hours. Since the unloading of ball mill takes half hour only, it's suggested that the unloading time is set at 7:30 Am. By doing so, the off-peak electricity can be completely used and the normal shift of 8:00 A.M. won't be delayed.

In the whole process, the other equipment is the continuous production type, excluding the ball mill; it's therefore the *load management measures cannot be implemented.*

3. The Running Characteristics Analysis of the Ceramics Processing Equipment

3.1 Foreword

This chapter concentrates on the running characteristics analysis of major equipment and that equipment with large power consumption in the ceramics industry. The focus will be put on the followings:

(1) The name and purpose of equipment
(2) Equipment capacity and process running time
(3) Running characteristics of equipment
(4) The analysis on the equipment power consumption
(5) The feasibility analysis of equipment in tune with load management strategies

3.2 The Characteristics Analysis of Ceramics Production Equipment

This research visited 12 ceramics manufactories, one of them produces particle materials for tile, and the rest is the integration plant from raw material to finished product. Their products include floor brick, wall brick, quartz brick and glass tile.

This section will depict the equipment characteristics of ceramics production procedure. The main production equipment is as follows:

(1) Ball mill (2) spray drying (3) forming machine (4) glazing machine (5) sintering furnace

(1) The Characteristics Analysis of Ball Mill

This equipment is to mill the stone of large grain size into particle or powder. Besides, the 35% of water is added to form slurry and prepared for spray drying later on. The equipment function divides into two categories, one is the stone milling, and the other is glaze milling. The power capacity of the former is bigger than that of the latter. Only electric power is the equipment's energy source. Generally speaking, its power capacity accounts for 44% ~ 56% of the whole production line. Its power consumption is rather large with the running time about 13 ~ 16 hours. The running time depends on the particle size. This equipment runs once a day, the rest time goes to feeding and unloading.

Since the milled slurry can be stored in the sink, this equipment can be individually stopped after milling in the ceramics process. Accordingly this equipment can be coordinated with the load management implementation of the interruptible rate and TOU rate. However there are no concrete measures for energy saving.

The power capacity of this equipment is about 600kw ~ 1150kw. It's running greatly influences the daily load curve of ceramics process. Therefore this equipment should be considered as the center target of load management in the ceramics process.

(2) The Characteristics Analysis of Spray Drying

This equipment injects the milled slurry into tower and blows the hot air into tower that is produced by the burning of heavy oil. The slurry is instantly dried into particle and falls down the bottom of tower naturally.

The thermal source of this equipment is the burning of heavy oil. And the tower work temperature from down to top is 100°C ~ 600°C (see figure 2.3). There is a ventilator in the lower tower to exhaust waste heat to the atmospheric layer, as the waste heat cannot be reused. The energy source of this equipment comes from electricity and heavy oil. The power capacity of this equipment is about 110kw ~ 260kw.

The operation of this equipment running is classified as the continuous production mode and cannot be singly stopped to cope with the load management of the interruptible rate. Besides this equipment can't be run in the off-peak hours. There are no concrete measures for energy saving.

(3) The Characteristics Analysis of Forming Machine

Through high, oil, or air compressor, this equipment forms the dried particle for the use of sintering in the next step. The power capacity of electricity equipment in the forming machine is about 200kw. Besides the cooling machine is served as the cooling of forming machine to avoid the mold damage. In general the cooling machine comes in ice water pump, the power capacity is 35kw ~ 50kw.

The running of this equipment is regarded as the continuous production mode and cannot be individually stopped to cope with the load management strategy. There's also no concrete measures for energy saving.

(4) The Characteristics Analysis of Glazing Machine

This equipment is to put the glaze on the formed compact. Based on the color classification, its process is divided into a few of screen, glazing and printing. Its power capacity is about 4kw ~ 11kw.

This equipment is also classified as the continuous production mode and cannot be singly stopped to cope with the load management of the interruptible rate.

(5) The Characteristics Analysis of Sintering Furnace

This equipment is to sinter the glazed compact into finished product with high temperature. The product quality completely depends on this equipment's running. According to product classification, this equipment is divided into two categories, one is open tunnel kiln with length of 70 ~ 90 meters. The thermal source is natural gas. The glazed compact is put on the cart and slowly enters the tunnel from the front. In the sintering process, it takes 30 ~ 40 hours to go through the whole tunnel with computer control of cart speed and becomes the finished product. This tunnel kiln is applied with process of brick and glass tile. The electricity equipment of this kiln includes ventilator, exhauster and drag motor with 55 KW in total. The other is roller hearth that is quite different from the former one in the operation method. The glazed compact directly enters the hearth from the front and goes through the whole hearth by the underneath bearing, which is full of roller. The thermal source is also natural gas with high work temperature of 1150°C. It takes 40 ~ 50 minutes to go through the whole hearth of 80 meters length and becomes the finished product.

Both electricity and natural gas are the energy source of this equipment. The electricity equipment includes ventilator, exhauster and drag motor and its power capacity is 110kw. Since this equipment is continuous production mode and can't be individually stopped to cope with the load management of interruptible rate.

4. Load Characteristics and Rate Analysis of Ceramics Industry

4.1 Foreword

The chapter 3 illustrates the process characteristics of different product. This chapter will study and analyze the rate policy of Taiwan Power Company. Afterwards the power consumption status of customer is observed through its daily load curve characteristics. In the meantime the electricity rate of customer is served to evaluate its potentiality in the load management participation. This chapter will also discuss the customer's various load factors in order to sum up the power consumption characteristics of the ceramics industry. [3][4][5]

4.2 The Analysis of the Load Characteristics and TOU Rate of Ceramics Industry

The load curve figure (figure 4.1 and 4.2) of two tile makers are served to realize the power consumption status of few tile makers with large production value. Their process and equipment are similar, however the power consumption status is different due to the process arrangement. This will affect the electricity expenditure of that customer. The figure 4.1 vividly indicates before 3:00 A.M., the off-peak power consumption is larger than the 8:00 A.M. on-peak power consumption. Yet the figure 4.2 shows the power consumption of on-peak hours is more than that of on-peak hours. The former indicates that TOU rate concept is deeply rooted in the management level and the process design. However the figure 4.2 shows that the customer leaves much to be desired in implementing the load management of TOU rate.

Based on the plant visit, these two customers have same problems, i.e. ball mill with large power consumption starts running in the on-peak hours (after 1:00 P.M.) for 14 ~15 hours, stops at 3:00 A.M. This will lead that four and half hours off-peak hours of power can't be used. This is the loss for both the Power Company and customer. The figure 4.2 customer B is served as an example to analyze that the effect of power consumption status and rate will produce if the ball mill changes the running time.

This customer has four sets of ball mill with total power capacity 2400kw. Its running method is: the first ball mill starts running around 12:00 P.M., as it's lunch break and can reduce high instant consumption for one hour. Afterwards three ball mills start running every one-hour. At 4:00 P.M. is the daily consumption climax. After 1:00 A.M. the ball mill shuts down one after another. This result in the off-peak power from shutdown to 7:00 A.M. cannot be used as clearly shown on the figure 4.2.

Customer B's demand contract capacity is 4300kw with total power capacity of 4713kw for major production equipment. While the power capacity of ball mill chalks up 56% of that of major production equipment. (About 53% of demand contract) If customer B can delay the running time of ball mill in four hours, it will decrease 2400kw x 4=9600 kilowatt-hour of on-peak power consumption. Though the off-peak power consumption will increase. It still saves the electric fee with 9600 x (NT$1.89 – NT$0.71)=NT$11,328.0 and don't affect its process.

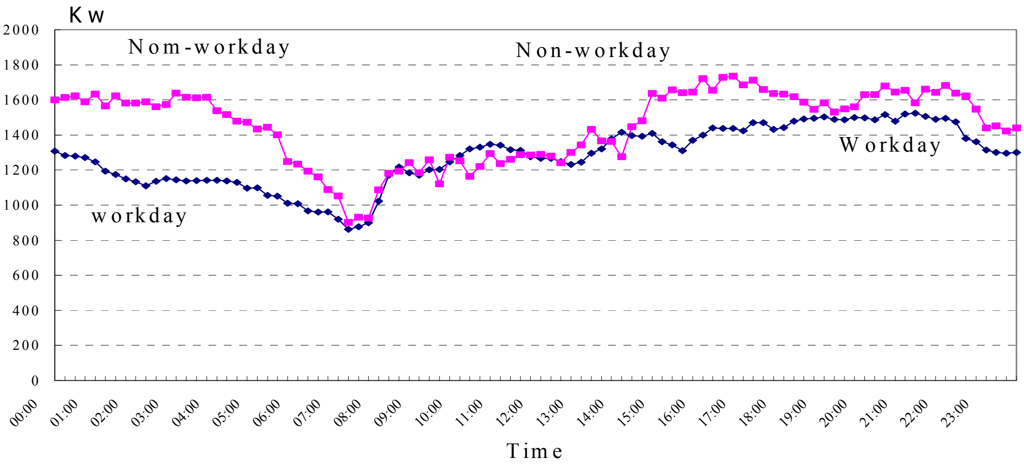


Figure 4.1 The Daily Load Curve Figure on Workday and Non-workday of Customer A

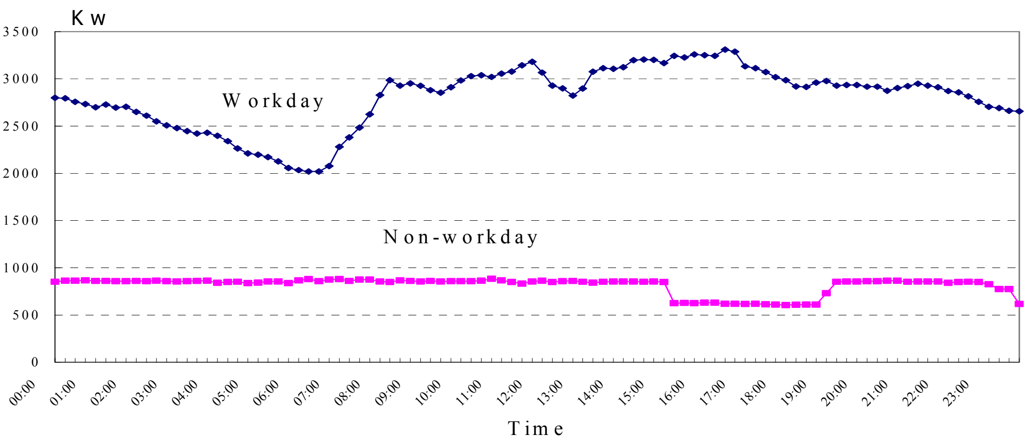


Figure 4.2 The Daily Load Curve on Workday and Non-workday of Customer B

Besides the figure 4.2 indicates the workday on-peak loading is about 3200kw workday is about 3200kw. This illustrates expresses that there's considerable contract allowance.

(1) The analysis on power consumption characteristics of customer

The customer's data is as follows:

- Company Name: Customer B
- Contract Capacity: 4300kw (regular)
- Equipment Capacity: 4700kw (see table 4.1)

Table 4.1 The Equipment Capacity of Customer B

Load Item	KW	%
Motor Load	3980	84.61
Electric Heat Load	665	14.22
Lighting	55	1.17
Total	4700	100

Figure 4.3 depicts that the monthly power consumption of customer B in 1999. It indicates that on-peak power consumption is higher than off-peak power consumption. For instance, on-peak power consumption in July is more than off-peak power consumption by 300,000 (kilowatt-hour).

(2) The analysis of power consumption characteristics of customer B is as follows

The average monthly power consumption of on-peak hours in summer (from June to September) is 1,038,000 kilowatt-hour, while non-summer is 827,000 kilowatt-hour. The average on-peak power consumption of summer is more than non-summer by 211,000 kilowatt-hour, and 25.51% growth rate. The average power consumption of off-peak hours in summer is 800,000 kilowatt-hour, while non-summer is 695,000 kilowatt-hour. The average off-peak power consumption of summer is higher than that of non-summer by 105,000 kilowatt-hour, and 15.10% growth rate.

In summer, the average power consumption of on-peak hours is more than off-peak hours by 238,000 (kilowatt-hour), and 29.75% growth. In non-summer, the average power consumption of on-peak hours is more than that of off-peak hours by 132,000 kilowatt-hour, and 18.99% growth rate. Figure 4.4 is the monthly rate of on-peak & off-peak hours in 1999 from customer B. From the figure, the on-peak rate is rather expensive than off-peak rate. Taking July for example, on-peak rate is more than off-rate by NT$1,500,000.0.

(3) The rate analysis of customer B is as follows

The average rate of on-peak hours in summer is NT$2,015,622.0, while that of non-summer is NT$1,571,938.0 posting NT$443,684.0growth at 28.22%. The average rate of off-peak hours in summer is NT$602,656.0, while that of non-summer is NT$49,926.0, registering NT$103,396.0 growth at 20.70%.

The average rate of on-peak hours in summer is more than that of off-peak hours by NT$1,412,966.0 posting 234.45% growth. While the average rate of on-peak hours in non-summer is more than that of off-peak hours by NT$1,072,678.0 experiencing 21.85% growth. Figure 4.4 indicates the monthly peak load in 1999 for customer B. Both the consumption climax of on-peak and off-peak hours does not exceed the demand contract of 4300kw that shows this customer controls the electric consumption very well. However figure 4.4 indicates that its daily peak load is 3200kw with difference of 1100kw to demand contract. As a consequence, the customer B can reduce the contract capacity or participate in the interruptible rate package to decrease the demand charge, in the meantime it can lower the power reserve margins of on-peak of Taiwan Power Company.

(4) The peak load analysis of customer B is as follows

The peak load usually occurs in June, August, September and December. The summer consumption climax of on-peak hours in average is 4068kw, and that of non-summer is 3865.625kw. The summer consumption climax of on-peak hours in average is more than that of non-summer by 202.375kw, up 5.23%. While the summer consumption climax of off-peak hours in average is 3812kw, and that of non-summer is 3522kw. The summer consumption climax of off-peak hours in average is higher than that of non-summer by 290kw, posting 8.23% growth.

To sum up, the customer B may adjusts the running time of ball mill without affecting the production process and can save a considerable energy rate. If this customer can join the interruptible rate package, the demand charge is also saved.

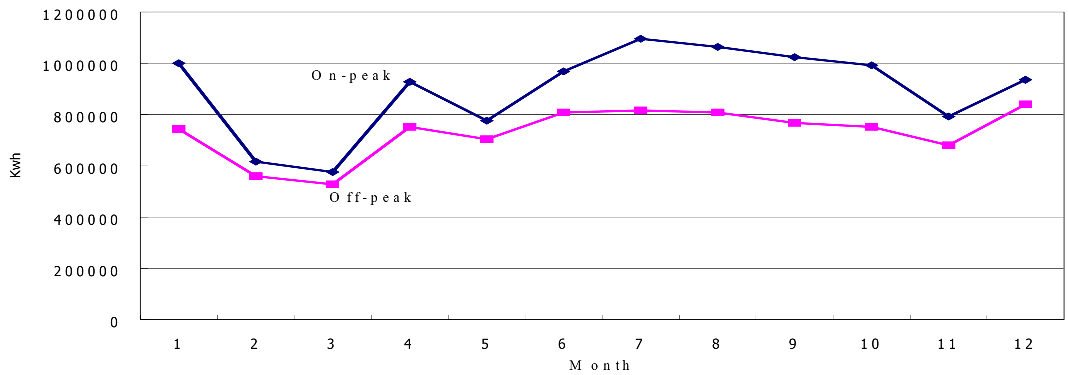


Figure 4.3 The Monthly Power Consumption Kilowatt-hour of On-peak and Off- peak Hours in 1999 of Customer B

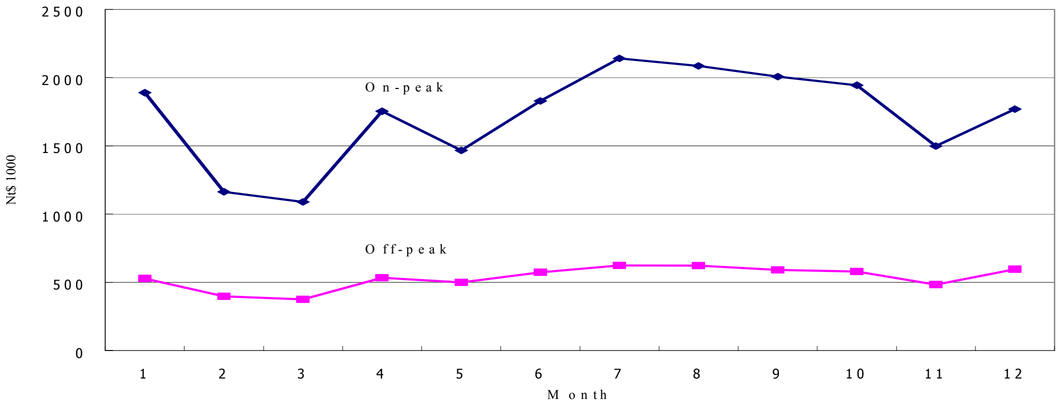


Figure 4.4 The Monthly Rate of On-peak and Off-peak Hours in 1999 of Customer B

4.3 The Analysis of Load Ratio of Daily

In table 4.2, the on-peak hours load ratio of most ceramics factories is within 60% ~ 80%. This table is calculated based on the consumption of every 15 minutes demand and regardless of time duration. It indicates that this type of customer favorites to use electricity during on-peak time. Therefore most of ceramics customers can save expenditure of energy rate by TOU rate.

Table 4.2 The Load Ratio of Daily On-peak Hours in the Sampling Week of Ceramics Factories

Name of Customer	The Load Ratio of On-peak Hours in the Work Day (%)					
	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
A (Ceramics)	68.3	63.1	60.9	75.0	64.1	66.9
B (Ceramics)	81.1	63.6	68.2	68.4	67.5	63.7
C (Ceramics)	72.2	60.1	65.8	67.0	62.3	55.1
D (Ceramics)	80.3	62.4	62.9	70.2	63.3	59.0
E (Ceramics)	76.6	62.9	54.8	71.5	63.2	64.5
F (Ceramics)	67.8	72.5	69.0	58.1	65.3	73.2
G (Ceramics)	70.1	65.8	67.2	63.1	67.0	67.2
H (Ceramics)	78.5	70.2	67.9	63.2	63.8	65.1
I (Ceramics)	64.1	63.6	62.9	62.4	62.7	63.0
J (Ceramics)	75.6	76.9	74.8	67.9	75.8	78.1
K (Ceramics)	80.8	65.2	64.3	62.7	54.2	65.8
L (Ceramics)	49.8	62.1	44.2	41.0	47.1	46.2
Average	72.1	65.7	63.7	64.2	63.0	64.0
Weekly Average	65.45					

4.4 The Analysis of Interruptible Load

Taiwan Power Company is proactively engaged in the power development and implements the various load management measures such as the interruptible rate, TOU rate and seasonal rate in continuous effort with the hope that the reliability of system power supply and clipped peak load can be increased. Taking the interruptible rate for example, Taiwan Power Company started the implementation since 1987 and expanded as well as revised its contents year by year. Based on the power system, the six different scope of the interruptible rate is planned for different industrial customer's selection. Besides according to its interruptible capacity, Taiwan Power Company has its demand charge discount, if the customer inks the contract with Taiwan Power Company.

4.5 The Load Demand Control Analysis

The control method of load consumption is another way to reduce electric cost. The load consumption in automatic control can prevent the customer from penalty of exceeding contract capacity. It means when the power consumption climbs up to the climax, this method can get rid of unimportant load or the interruptible electricity equipment.

The rate, which Taiwan Power Company charges to the industrial customer, is the total power consumption in each month, i.e. how much is one kilowatt-hour? In addition, the added rate is defined as "how much is the power consumption climax in one month." The load control device of power consumption aims to prevent the occurrence of new climax with the hope of reducing the added rate. [6]

Owing to the deviation factor, all electricity equipment doesn't operate at the same time. Besides the power consumption is in the status of dynamic variation due to the reasons of the boom-and-bust, season or production and sale plan. The customer has to carry out the control management of load consumption, if the purpose of the economical use on the electricity equipment is required. The monthly power consumption can be reviewed at any time to decrease the electricity cost. [7]

4.6 The Analysis of the Optimal Demand Contract

With the rapid growth of air conditioner load, the peak loading of customer in summer daytime period increases dramatically and the condition of peak loading in 15-minute leading demand contract becomes more serious. According to the electric price system in TPC, customers are asked to pay extra cost with respect to the portion of basic fee in the case that the peak loading is higher than the demand contract. On the other hand the inappropriate higher demand contract setting can avoid the occurrence of previous stated problem but will results another problem of higher basic electric fee payment. The basic idea of optimal demand contract strategy is to derive a better demand contract such that the annual electric basic cost can be minimized.

Figure 4.5 shows the schematic diagram of optimal demand contract derivation. In this figure, twelve months time intervals with different monthly peak loading are selected to describe the derivation of optimal demand contract for high-tension customer. In the months of 1,2,3,11, and 12, the monthly peak loading P_{imax} is lower than the demand contract but it is still required to pay basic electric fee with demand contract P_{DC} the blocks with dashed line show the lost cost due to the insufficient peak loading. Besides, the peak loading P_{imax} in remained months are larger than the demand contract and the extra payment for electric fee is required. The dashed blocks in these months express the penalty cost for basic electric fee. The smaller area of dashed blocks has, the lower extra payment of electric fee has. It is indicated that the minimization of the area of these dashed blocks will introduce the optimal demand contract.

The computation of monthly electric basic fee in three conditions is expressed as follows. Based on Eq. (4.1), the formulation of optimal demand contract with linear programming form is obtained in Eq. (4.2). In this equation The only one inequality constraint is the P_{opt} is within the interval of between P_{min} and P_{max} Also the terms of Ci(P_{opt}), and EC(P_{opt}.) mean the basic electric fee and extra payment. It is noted that the P_{opt} affects both these two terms.

The calculation of monthly electric basic fee is shown as follows:

Where:

$$CB = \begin{cases} P_{DC} \times S \ ; \ P_{i\max} \le P_{DC} \\ P_{DC} \times S + (P_{i\max} - P_{DC}) \times 2 \times S \ ; \ P_{DC} < P_{i\max} \le 1.1 P_{Dc} \\ P_{DC} \times S + 0.2 P_{DC} \times S + (P_{i\max} - 1.1 P_{DC}) \times 3S \ ; \ P_{i\max} > 1.1 P_{DC} \end{cases} \tag{4.1}$$

CB : monthly electric basic fee

P_{DC}: demand contract engaged with TPC kw

S : coefficient NT$207 /kw

P_{imax} : customer monthly peak loading kw

The formulation of optimal demand contract is expressed as follows:

$$\min \sum_{i=1}^{12} \left[C_i(P_{opt}) + EC(P_{opt}) \right] \qquad \text{Subject to} \qquad P_{\min} \le P_{opt} \le P_{\max} \tag{4.2}$$

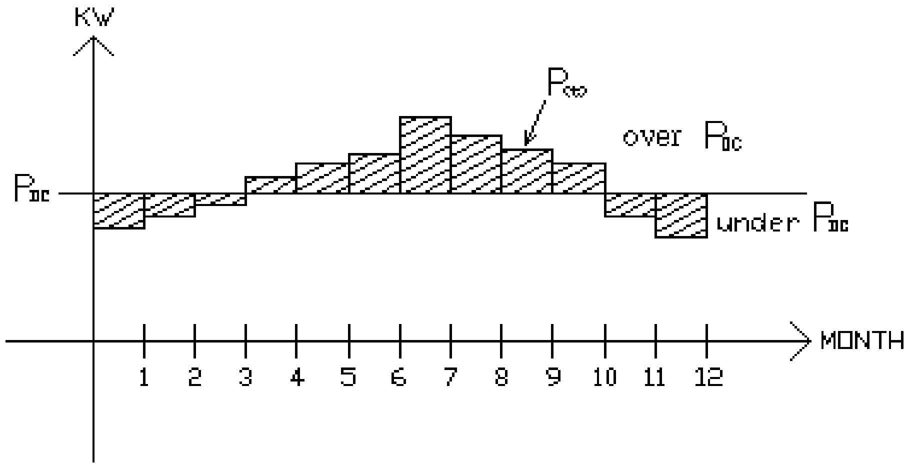


Figure 4.5 The Schematic Diagram of Optimal Demand Contract Selection

Table 4.3 The Analysis of Optimal Demand Contract Select (Customer B)

Month	Kw (Monthly peak loading)	
January	3650	The scope of peak loading：3491kw~4002kw
February	3497	
March	3582	Regular contract capacity：4300kw
April	3491	
May	3520	Optimal demand contract：3904kw
June	3912	
July	3822	Optimal contract fee：NT$662,228 /year
August	3595	
September	4002	Non-optimal contract fee：NT$1,815,164 /year
October	3917	
November	3904	Customer B saves NT$1,152,936 /year
December	3935	

The analysis on the basic demand charge is as follows:

If customer B select optimal contract capacity (3904KW), it will save annual rate of (NT$1,815,164 - NT$662,228)=NT$1,152,936 annual rate.

5 The Determination of the Load Management Strategy for the Ceramics Industry

5.1 Foreword

This chapter describes the information collection, willingness of participating load management options for the ceramics industry and then the load of management strategies. It includes (1) the implementation of TOU rate (2) the participation of interruptible load rate (3) the load demand control automatic control (4) the selection of optimal demand contract.

5.2 The Analysis of Information Collection

1. The questionnaire and visit sheet of this research aim to survey, collect and analyze the process characteristics industry, production procedure and the equipment power consumption of the ceramics industry.
2. The sampling target of this research focuses on the 29 ceramics factories with large power consumption.
3. The sampling of questionnaire and visit sheet is attached as Appendix A (omit).
4. The person need to response the questionnaire or receive the visit is in charge of the production department or the electricity technology aspect.
5. Mail and the telephone as follow-up to increase the return rate conduct the questionnaire.
6. The visit is conducted either by telephone or plant visit.

7. Since most of respondents hope to keep the company information as confidential, therefore this research won't open the basic information of the respondents.
8. The total visited ceramics factories are 12. (It was originally scheduled to visit 29 factories with large power consumption, yet some of them were not willing to receive the visit.)
9. This research has mailed 100 questionnaires with 15 effective returned, the return ratio is low (15%).
10. After compiling and analyzing the returned questionnaires and the collected information of plant visit, this research found out: (a) The process characteristics of the ceramics industry shares the process characteristics similar in the production procedure, furthermore; most of them are almost the same. (b) The majority of Taiwan ceramics industry favorite to use the electricity in the on-peak hours.

5.3 The Analysis of Implementation of TOU Rate (Strategy One)

During the plant visit, the customers expressed their interests in the daily load curve figure of the power consumption. In line with the power consumption and rate analytical figure of on-peak & off-peak hours provided by this research, the customer realizes that the TOU rate measures will save its electricity cost in very short time. Thus the customer participates in the load management options. Meanwhile, the customer will consider how to change process to cope with various beneficial rate options provided by Taiwan Power Company.

Due to the characteristics of process and equipment running, the ceramics industry can further implement the TOU rate options.

5.4 The willingness of participating the Interruptible Rate (Strategy Two)

The customer usually operates in the full load production. Yet under the recession impact, the actual peak load has already decreased to 75% of the original demand contract or it has been lower than that. It can be realized by introducing between the peak load and the demand contract of daily load curve. It is therefore suggested that the customer should review its actual load capacity to well coordinate with power consumption. The reduction of demand contract or participating the interruptible rate package can be the alternatives to drop down demand charge. Besides the customer can arrange the equipment of the original production line under the condition non-full loaded. Meantime the production procedure and time can be re-planned and arranged to avoid the concurrent operation of heavy load equipment which will result in the very high load demand can not be reduced.

Since the customer worries about damaging the semi-product; they will transfer the process to the night and thus increase the difficulties on management. The analysis and suggestion are as below.

The customer so-called management difficulties include:

(1) The personnel cost will increase in the night production

Based on the plant visited, the major production equipment in the process for many customers turns into automatic production. The inspection and packaging parts need much crew. Since the technical level of these parts is low, the alien laborer can process it. As the wage of alien laborer is lower, this difficulty can be overcome after detail calculation.

(2) The key management personnel are unwilling to join the night production.

Only the experienced management personnel are capable of formula and process control, the customer has to consider their willingness in joining the night production into consideration if the implementation of night production is preceded. In the smooth condition, it may not be easy to persuade the management personnel into working in the night. However the management personnel should brave the tough times and participate in the night production under the current worse condition of production and sale.

(3) The stipulations of Labor Standards Laws

The current Labor Standards Laws clearly and strictly stipulate the women participation in the night production. Besides the measures on the limitation of working hours and traffic safety for women are the hindrances for the customer to implement the night production.

5.5 The Analysis on the Load Demand Control (Strategy Three)

In the plant visited, the customer expressed willingness in the load demand control, but the installation of automatic load controller need extra operation cost which therefore reduce the participation willingness from the customer. From the long-term viewpoint, this load management strategy will save electricity cost for the customer. After the explanation, the customer can accept the concept and will proceed to implement this alternative

.

5.6 Implementation of Optimal Demand Contract (Strategy Four)

In the plant visit, the optimal contract capacity is not well implemented for customer. As the customer roughly estimates the optimal demand contract based on the historical information and doesn't rigidly analysis by the mathematical method. Thus the expenditure of demand charges increase. After explanation and analysis, the customer willingly precedes the implementation of optimal contract capacity.

6. Conclusions and Suggestions

6.1 Conclusions

1. The product classification and process of the ceramics industry are fully understood through this research. Besides, the survey results of plant visit, daily load curve of power consumption and rate analysis are considered. Therefore the suggestion is submitted on the adjustment of ball mill running time for the ceramics industry. This suggestion is considerably welcome from the ceramics industry.
2. The ceramics industry is much willing to participate in the interruptible load rate package.
3. The ceramics industry is also willing to install the automatic load demand controller.

6.2 Suggestions

1. It is recommended that the running time of ball mill should be adjusted to 4:00 P.M. in tandem with the TOU rate to reduce electricity cost.
2. It is suggested that the customer should review the ratio between current capacity and demand contract in order to decrease the demand contract or participate in the interruptible rate package for the reduction of demand charge.
3. It is recommended that the customer should adopt the load demand control to automatically adjust load as long as the load consumption varies so that the peak load won't exceed the demand contract.
4. The final suggestion is that the future research shall focus on the analysis of power consumption characteristics for the various industries with large power consumption.

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