v. 3, n. 30, 2023

Journal of
Engineering
Research

SAVINGS POTENTIAL DUE TO DEMAND MANAGEMENT IN REFRIGERATION SMES

Mauricio Ivan Huchin Miss
Universidad Autónoma de Campeche
San Francisco de Campeche – Campeche
0000-0002-5669-9098

Germán Escalante Notario
Universidad Autónoma de Campeche
San Francisco de Campeche – Campeche
0000-0002-5900-4570

Meng Yen Shih
Universidad Autónoma de Campeche
San Francisco de Campeche – Campeche
0000-0001-7475-6458

Francisco Román Lezama Zárraga
Universidad Autónoma de Campeche
San Francisco de Campeche – Campeche
0000-0003-3397-7881

Abstract: This paper deals with the problem of a low load factor (30%) in a food refrigeration SME and presents a methodology that allowed determining economic savings of up to $16,176.57 MNX per month by increasing this value by up to 76%. The study focused on knowing the demand profile of the company located in San Francisco de Campeche-Mexico, through a second level energy diagnosis. In addition, measurements were made, using an AEMC 3945-B network analyzer. Using this information, consulting the supplier company's website and processing the information in spreadsheets, the estimated savings were determined.
Keywords: Diagnosis, saving, refrigeration, demand, load factor.

INTRODUCTION

The efficient use of electrical energy in the manufacturing facilities of SMEs is conditioned by the different technologies installed and the way in which they are operated (startup and stoppage) to solve the variability of production in the different months of the year.

In order to know in detail the behaviors and determine potential energy and economic savings, energy diagnoses are a key tool that allow proposals for improvement to be made based on the analysis of information obtained.

In the case of facilities whose main final use of energy is refrigeration systems for the conservation/freezing of seafood, the variability of production affects the indicators of energy use in the facilities, that is, the factor power and load factor; Therefore, through the analysis of these, savings can be determined that benefit economically and prioritize energy efficiency projects that improve the indicators. It is estimated that refrigeration systems for the food and beverage industry represent 30% to 40% of energy costs (CONUEE, 2021), so it is important to optimize energy use, especially in the peninsular region where These types of SMEs are found more frequently due to the local demand for seafood products.

Given this, the objective of the work focuses on determining the potential for economic savings by improving the load factor of a fish and shellfish manufacturing facility, taking the data for the year 2019 as a baseline.

Through the work, the savings that can be had by managing the demand and increasing the load factor of the installation are highlighted.

INSTALLATION FEATURES

The company is dedicated to the capture, processing and commercialization of sea products from the state of Campeche. The areas that make it up are: Reception, bathrooms, corridors, kitchen, pump room, product processing rooms, packaging and warehouse area, laundry area, meeting room and various accounting, administration, quality control, process offices., and product monitoring

The electrical energy received by the installation is through a medium voltage pedestal-type substation at the High Demand Medium Voltage Hourly rate, the characteristics are shown in Table 2.1.

Type	Pedestal
Capacity	225 kVA
Number of phases and wires	3F - 4H
Frequency	60 Hz
Voltage in medium voltage	13200 V
low voltage voltage	220/127 V
connected load	180 kW
contracted demand	180 kW

Table 2.1 Substation characteristics

From the survey of loads of the installation, it was found that the final uses of energy correspond to lighting, air conditioning, office equipment, refrigeration, motors and pumps as shown in Figure 1. A significant use of energy is observed for refrigeration used for the conservation and freezing of fish and shellfish.

ELECTRIC BILLING ANALYSIS

In the analysis of consumption, the seasons of low, medium and high production were detected, as shown in Figure 3.1. In the low season it is observed that in the months of January and February the energy consumed at peak is similar to that of May and September in the medium and high seasons respectively. In addition, the peak energy in March of the low season is higher than in July and August of the shoulder season. This abnormal behavior does not correspond to an efficient use of energy. The correct thing would be that in the low season the lowest consumptions will be presented at peak hours. For the high season, an atypical increase in peak consumption is observed in the month of November.

Regarding base and intermediate consumption, no abnormal behavior is observed, since, in each season, consumption increases depending on production.

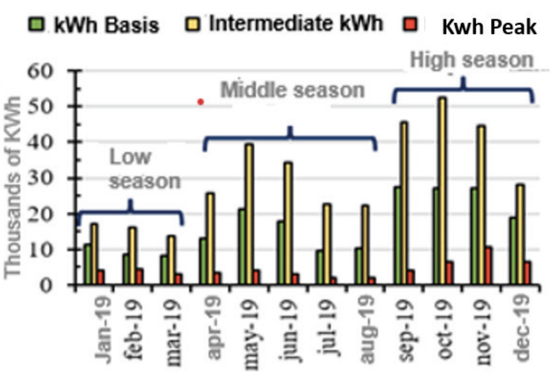


Figure 3.1. Energy consumption in the installation (CFE, 2019)

Regarding the power demand, it can be seen in Figure 3.2 that the intermediate demand presents the highest value during the medium production season. In peak hours, it is desirable that it have the lowest demand value or values close to the base demand, however, for the month of October it is observed that it exceeds the demand in intermediate hours and in the month of November it coincides with the demand in intermediate hours. According to the production, the high season is the one that must have the greatest demand, but it is in the month of May (middle season) that the highest value is presented.

The base demand maintains a behavior similar to that of intermediate and rush hours. This represents an opportunity for improvement since the behavior from March to July and from August to December shows a lack of management regarding the start and stoppage of the equipment. In addition, the values are lower, but this is due to the fact that the base load of the installation, such as lighting, air conditioning, and office equipment, are no longer operating during these hours.

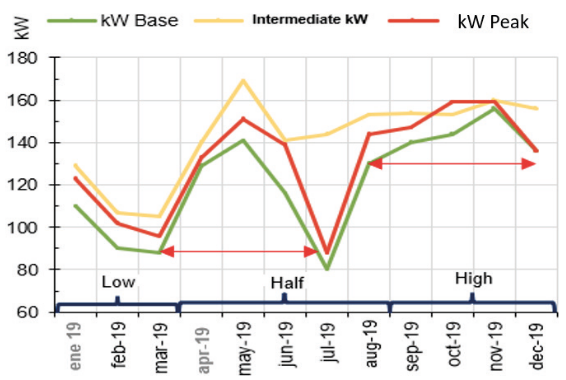


Figure 3.2. Power demand in the installation (CFE, 2019)

The evaluation of the correct start-up and stoppage management of the equipment is carried out by means of the load factor (FC) value indicator of the installation as shown in Figure 3.3. For this installation, the values are in the range of 30% to 76% and closer to 100% means better power demand management. In addition, higher values of load factors decrease the average price of energy, for example, for 76% the average price is $2.4342/kWh, while for 30% it is $2.7378/kWh. To increase the values of load factors, the equipment must operate for a longer time and avoid frequent starting and stopping, hence the relevance of management.

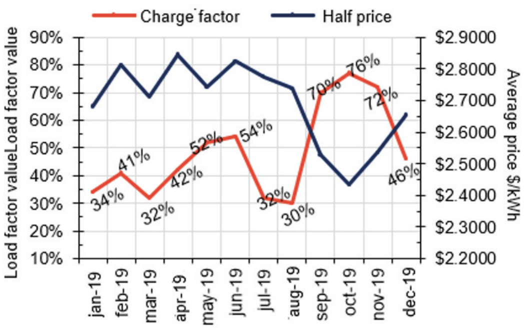


Figure 3.3. Load factor and average price at installation (CFE, 2019)

Figure 3.4 shows that the average power factor in the low season is 93.62%, in those months, a limited amount of equipment is operating so that the required reactive power is lower. In the middle season the value remains at 92.54%, while in the high season the value decreases to 87.34%, this is due to the greater use of equipment during this season. The constant starting and stopping of each of these pieces of equipment implies magnetization or vacuum currents necessary for the creation of the magnetic field of the electric charges that translate into a greater demand for reactive power.

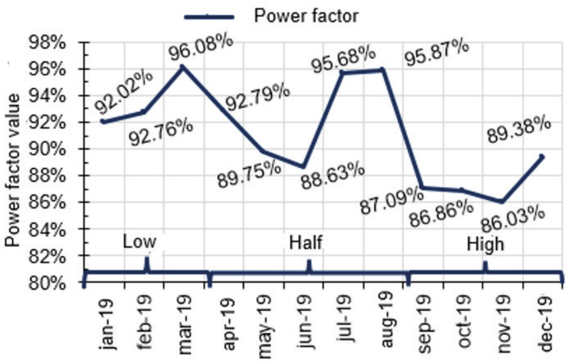


Figure 3.4. Power factor in the installation (CFE, 2019)

If we compare the power factor values with those of the load factor, it is observed that the lower load factor values correspond to the higher power factor values that occur in the low season, while high load factor values are consistent. to low values of power factor in the high season. This demonstrates a lesser or greater use of equipment according to the seasons.

POWER DEMAND PROFILE

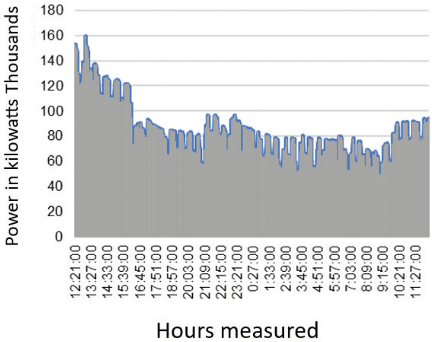
In order to understand the power demand, it is necessary to know the active power demand profiles of a representative interval that can be between 1 week and 1 month where the behavior of the different production and operation schemes is reflected, installing at least temporarily an equipment of measurement or network analyzer with memory (Flores, 2003). For this, measurements were made in the high season, in the period from September 3 to September 10, 2019.

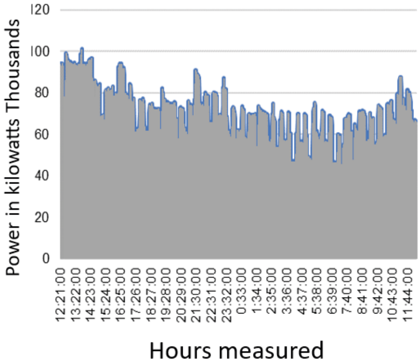
The maximum and minimum values recorded are shown in Table 4.1

Poower (kW)	
Maximum	159.5
Minimum	17.5
Medium	93.7

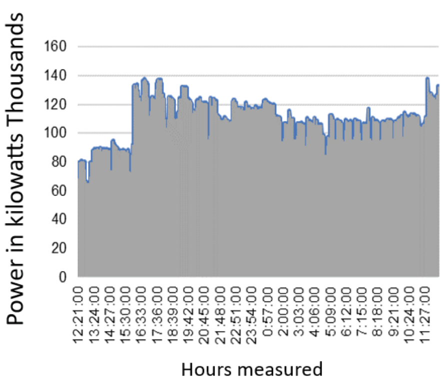
Table 4.1. measured active power

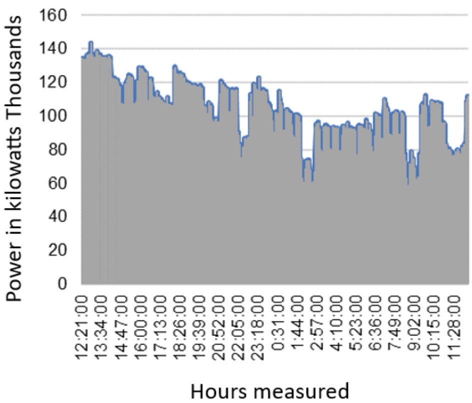
When comparing the maximum demand registered with that contracted, a use of 88.6% was determined. This is related to the lack of management of the demand for starting and stopping the equipment, which causes a continuous variation in the behavior of the demand, as observed in Figures 4.1 to 4.7.



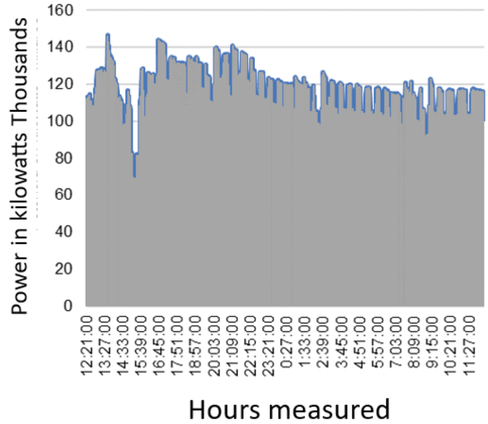


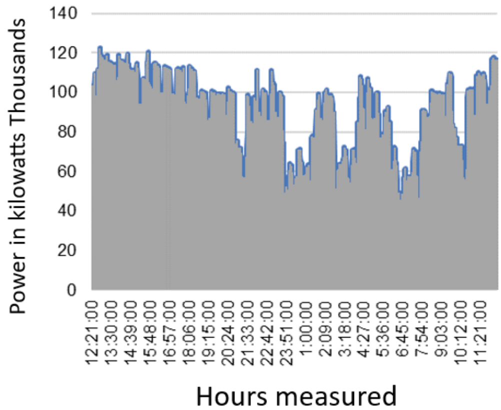
Figures 4.1 and 4.2 Behavior of the power demand day 1 (left) and day 2 (right)



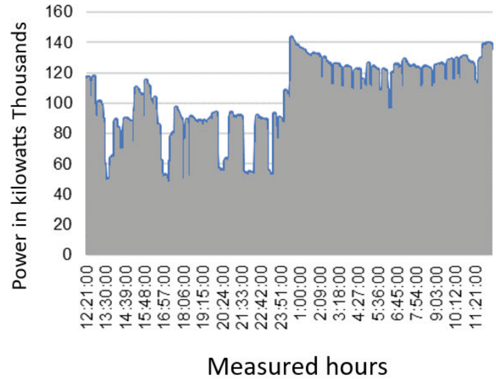


Figures 4.3 and 4.4 Behavior of the power demand day 3 (left) and day 4 (right)





Figures4.5 and 4.6 Behavior of the power demand day 5 (left) and day 6 (right)



Figures 4.7: Behavior of power demand day 7

Therefore, in graph 4.1 (day 1), the average demand remained at 80 kW and the maximum peak was 159 kW.

In graph 4.2 (day 2), the average demand remained at 70 kW and the peak demand exceeded 100 kW.

In graph 4.3 (day 3), the average demand was 110 kW and the maximum demand was 140 kW.

In graph 4.4 (day 4), the demand peak exceeded 140 kW and there was a greater demand variation in the 120, 110, 100 and 90 kW hours.

In graph 4.5 (day 5) the average remained at 120 kW and the demand peak close to 150 kW.

In graph 4.6 (day 6), again variations in average demand from 60 kW to 100 kW are observed, up to maximum values of 120 kW.

In graph 4.7 (day 7), the values initially vary from 50 kW to 120 kW and subsequently remain on average at 130 kW.

In terms of management, the higher the power demanded, the lower the load factor will be, generating an increase in the average price of energy.

LOAD FACTOR ANALYSIS

The load factor provides a measure of the utilization of the installed capacity. Its value is expressed as a percentage and the higher it is, the better use will be made of the installed capacity in system elements such as transformers, conductors and generators. If the FC < 70% means a low use of the installed capacity (Vallin, Santos and Llamo, 2018).

According to the Federal Electricity Commission, the load factor is the ratio of the energy actually consumed in the period and the energy consumption considering 100% use of the facilities, that is, using the maximum demand registered in that same period., as shown in equation 5.1:

$$FC = \frac{energy\ consumed}{D_{max} * \frac{24\ h}{diday} * \frac{Number\ of\ days}{month}} \quad (5.1)$$

The number of days depends on what is indicated on the electric bill, so it can vary 28, 29, 30 or 31 days.

To carry out the analysis, the information shown in Table 5.1 will be used:

2019	kWh consumed	Basis kW	Intermediate kW	kW Peak	Maximum demand kW
Jan	32812	110	129	123	129
Feb	29454	90	107	102	107
Mar	25053	88	105	96	105
Apr	41950	129	140	133	140
May	64830	141	169	151	169
Jun	55180	116	141	139	141
Jul	34425	80	144	88	144
Aug	34700	130	153	144	153
Sep	77119	140	154	147	154
Oct	86099	144	153	159	159
Nov	82573	156	160	159	160
Dec	53514	136	156	136	156

Table 5.1. Case Study Baseline

Table 5.2 shows the total energy consumed and the energy consumption considering the maximum demand value for the same period, from these values we determine the load factor value.

2019	kWh consumed	kWh for maximum demand	Charge factor
Jan	32812	95976	34%
Feb	29454	71904	41%
Mar	25053	78120	32%
Apr	41950	100800	42%
May	64830	125736	52%
Jun	55180	101520	54%
Jul	34425	107136	32%
Aug	34700	113832	30%
Sep	77119	110880	70%
Oct	86099	113832	76%
Nov	82573	115200	72%
Dec	53514	116064	46%

Table 5.2. Calculated load factor

The load factor value indicates the ratio of the energy actually consumed compared to the calculated kWh per peak demand.

From the kWh consumed, we can calculate the associated average demand, using equation

Journal of Engineering Research ISSN 2764-1317 DOI 10.22533/at.ed.31733023140910

5.2:

$$Average\ demand = \frac{energy\ consumed}{hours\ period} \tag{5.2}$$

This average demand indicates the average value of kW that the installation must have and thereby improve the load factor.

As observed in Table 5.3, there is a significant difference between the average demand values calculated and the demand values in the base, intermediate and peak hours.

2019	Period hours	Average demand kW	Basis kW	Interme-diate kW	kW Peak
Jan	744	44	110	129	123
Feb	672	44	90	107	102
Mar	744	34	88	105	96
Apr	720	58	129	140	133
May	744	87	141	169	151
Jun	720	77	116	141	139
Jul	744	46	80	144	88
Aug	744	47	130	153	144
Sep	720	107	140	154	147
Oct	744	116	144	153	159
Nov	720	115	156	160	159
Dec	744	72	136	156	136

Table 5.3. Average demand against base, intermediate and peak demand

When analyzing these power values, we find that there are significant percentage differences (greater than 100%) when comparing it against the base, intermediate and peak demand, as shown in 5.4. These differences are due to the lack of control or management of the start and stop of the various electrical equipment.

2019	Variation of average demand vs. base demand	Variation of average demand vs. intermediate demand	Variation of average demand vs peak demand
Jan	149%	193%	179%
Feb	105%	144%	133%
Mar	161%	212%	185%
Apr	121%	140%	128%
May	62%	94%	73%
Jun	51%	84%	81%
Jul	73%	211%	90%
Aug	179%	228%	209%
Sep	31%	44%	37%
Oct	24%	32%	37%
Nov	36%	40%	39%
Dec	89%	117%	89%

Table 5.4. Variation of average demand against base, intermediate and peak demand

In the month of October, the lowest percentage variations are observed, since the average demand value and the demand values of the different hours are close, so that the highest load factor occurs in this month.

There are two alternatives that allow controlling the demand values and increasing the load factor, either by manual means or through a device called a controller. In both cases, the maximum load operated simultaneously is regulated so as not to exceed the maximum value of a determined operating point. If the regulation is manual, the operation of different loads must be programmed in such a way that the operation of certain loads is restricted during a period or operation times can be defined for each of the areas of the installation. Demand behavior must be monitored through measurements on the main dashboards. If the regulation is through a controller, it will be in charge of turning off certain loads temporarily to keep the maximum demand under control, through one of the following methods (Esparza and Altamira, 2002):

Instant upload method: EThe power level is continuously measured and compared to the preselected reference point. It is recommended in facilities with a continuous operating regime where there is little load variation throughout the work day.

Cumulative demand method: It is based on the relation of the accumulated demand and the reference limits of high and low permissible demand increasing over time.

Demand Curve Projection: It searches for the value of the demand at time t+1, so the controller's actions anticipate the moment in which the preselected reference is exceeded. It is recommended in installations where there are continuous power variations.

ECONOMIC IMPLICATIONS

Based on the load factors calculated in table 5.2, the savings in the installation can be estimated by implementing demand control and increasing the load factor. For this, the demand values in base, intermediate and peak hours of the period that had the highest load factor (October) must be compared against the period that had a low load factor (AMERIC, A.C., 2022). Figures 6.1 and 6.2 show the consumption, demand and cost data for the month of December and October respectively.

In each case, the demand represents 39% and 32% of the energy concept.

To determine the savings from increasing the load factor from 46% to 76%, the average demand for the month of October and the percentage variations in base, intermediate and peak hours must be determined, as shown in equations 6.1 to 6.4:

$$average\ demand = \frac{86099\ kWh}{744\ h} = 116\ kW \qquad (6.1)$$

$$base\ variance = \frac{144-116}{116} = 0.2414 \qquad (6.2)$$

$$interim\ variation = \frac{153-116}{116} = 0.3189 \qquad (6.3)$$

$$tip\ variation = \frac{152-116}{116} = 0.3103 \qquad (6.4)$$

In the case of the month of December the average demand is:

$$average\ demand = \frac{53514\ kWh}{744\ h} = 72\ kW \qquad (6.5)$$

Therefore, to increase the load factor from 46% to 76%, the base, intermediate and peak demand for the month of December must be:

$$Basis = 72 * 1.2414 = 90kW \qquad (6.6)$$

$$Interm = 72 * 1.3189 = 95kW \qquad (6.7)$$

$$Point = 72 * 1.3103 = 95kW \qquad (6.8)$$

By replicating these values for the month of December maintaining the same energy consumption, the results of Figure 6.3 are obtained.

From the data shown the load factor is 76% and the savings will be $173,306.40-$157,129.83=$16,176.57.

CONCLUSIONS

From the results obtained in the case study, it is concluded that:

1. The load factor can be improved in the range of 70% to 80%, managing the demand in the base, intermediate and peak hours, as described in the economic implications section.

2. The average economic savings potential will be greater than $15,000 MNX per month or up to $180,000 MNX per year that may be used for other alternatives for continuous improvement in the facility.

3. The demand profile obeys continuous power variations of 50, 60, 70, 80, 90, 100, 110, 120, 130, 140 and 150 kW in the 7 days that measurements were made due to the various loads that were are in operation, so a manual control will not

Concept			Current Reading	
kWh Basis			18807	
kWh Intermediate			28242	
kWh Peak			6465	
Months				
kWBasis			136	
Intermediate kW			156	
kW Peak			136	
Month				
kW Max Moving Year			127.0	
kVArh			26852	
Power Factor			0.8938	
	Capacity		127	
	Distribution		127	
	$	**$/kW**	**$/kWh**	**Amount**
Supply	$512.44	$0.00	$0.00	$512.44
Distribution	$0.00	$11,127.74	$0.00	$11,127.74
Transmission	$0.00	$0.00	$8,899.38	$8,899.38
CENACE	$0.00	$0.00	$417.41	$417.41
Generation B	$0.00	$0.00	$16,856.71	$16,856.71
Generation I	$0.00	$0.00	$45,850.89	$45,850.89
GenerationP	$0.00	$0.00	$11,838.06	$11,838.06
Ability	$0.00	$42,912.03	$0.00	$42,912.03
SCNMEM	$0.00	$0.00	$288.98	$288.98
Total	$512.44	$54,039.77	$84,151.43	$138,703.64

Concept	
Fixed charge	$512.44
Energy	$138,191.20
2% low voltage	$2,774.07
FP	$577.29
Subtotal	$142,054.99
IVA 16%	$22,728.80
Fac. Period	$164,783.79
DAP	$8,522.61
TOTAL	$173,306.40

Figure 6.1 Invoice for the month of December (CFE,2019)

Concept			Current Reading	
kWh Base			27243	
kWh Intermediate			52346	
kWh Peak			6510	
Mes				
kW Base			144	
Intermediate kW			153	
kW Peak			152	
Month				
kW		204.0		
MaxRollingYear		49112		
kVArh		0.8938		
Power Factor	Ability	152		
	Distribution	153		
	$	**$/kW**	**$/kWh**	**Amount**

Supply	$512.44	$0.00	$0.00	$512.44
Distribution	$0.00	$13,405.86	$0.00	$13,405.86
Transmission	$0.00	$0.00	$14,318.26	$14,318.26
CENACE	$0.00	$0.00	$671.57	$671.57
Generation B	$0.00	$0.00	$24,417.90	$24,417.90
Generation I	$0.00	$0.00	$84,983.73	$84,983.73
GenerationP	$0.00	$0.00	$11,920.46	$11,920.46
Ability	$0.00	$51,359.28	$0.00	$51,359.28
SCNMEM	$0.00	$0.00	$464.93	$464.93
Total	$512.44	$64,765.14	$136,776.86	$202,054.44

Concept	
Fixed charge	$512.44
Energy	$201,542.00
2% low voltage	$4,041.09
FP	$840.95
Subtotal	$206,936.48
IVA 16%	$33,109.84
Fac. Period	$240,046.32
DAP	$8,522.61
TOTAL	$248,568.93

Figure 6.2 : Invoice for the month of October (CFE,2019)

Concept	Current Reading
kWh Basis kWh	18807
Intermediate kWh	28242
Peak	6465
Month	
kWBasis	90
kW Intermediate	95
kW Punta	95
Month	
kWMaxRollingYear	127.0
kVArh	26852
Power Factor	0.8938
Ability	95
Distribution	95

	$	$/kW	$/kWh	Amount
Supply	$512.44	$0.00	$0.00	$512.44
Distribution	$0.00	$8,323.90	$0.00	$8,323.90
Transmission	$0.00	$0.00	$8,899.38	$8,899.38
CENACE	$0.00	$0.00	$417.41	$417.41
Generation B	$0.00	$0.00	$16,856.71	$16,856.71
Generation I	$0.00	$0.00	$45,850.89	$45,850.89
GenerationP	$0.00	$0.00	$11,838.06	$11,838.06
Ability	$0.00	$32,099.55	$0.00	$32,099.55
SCNMEM	$0.00	$0.00	$288.98	$288.98
Total	$512.44	$40,423.45	$84,151.43	$125,087.32

Concept	
Fixed charge	$512.44
Energy	$124,574.88
2% low voltage	$2,501.75
FP	$520.61
Subtotal	$128,109.68
IVA 16%	$20,497.55
Fac. Period	$148,607.22
DAP	$8,522.61
TOTAL	$157,129.83

Figure 6.3: New invoice for the month of December

be enough to improve the load factor.

4. A demand controller must be selected that operates using the curve projection method to compensate for continuous power variations and to be able to increase the load factor.

5. The average price of energy decreases from \$2.65/kWh to \$2.39/kWh. A difference of 26 cents, which when taking into account the 53,514 kWh consumed in December, corresponds to a saving of \$13,913.64 MXN.

6. Taking into account the potential for average economic savings by improving the load factor to 76% and the average price of energy, it is

1. establece que el intervalo de ahorro será de \$13,913.64 -\$ 15,000 MNX.

THANKS

This study is part of the project “Potential for economic savings by demand management in refrigeration SMEs”

REFERENCES

AMERIC, A.C. (2022, Enero 10). Análisis de precio por concepto de Facturación CFE [video]. https://www.youtube.com/watch?v=43eKXRA7Fqo&list=LL&index=27&t=1145s

Comisión Federal de Electricidad (CFE). Facturas de energía eléctrica del 2019.

CONUEE. (2021). Catálogo de medidas en eficiencia energética para la industria de alimentos y bebidas de México: Recuperado de https://www.conuee.gob.mx/transparencia/boletines/manuales/Catalogo_EE_Alimentos_Bebidas_Mexico_Conuee_02-03-2021.pdf

Esparza González, M. y Altamira Rodríguez, J. (2002). Controlador de demanda máxima. Recuperado en 19 de abril de 2022, de https://www.ruelsa.com/cime/boletin/2005/bt08.pdf

Ferrer Vallin, M., Santos Fuentefria, A. y Llamo Laborí, H. (2018). Análisis del factor de carga de un sistema eléctrico aislado con fuentes renovables de energía. *Ingeniería Energética*, *39*(1), 13-20. Recuperado en 19 de abril de 2022, de http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S1815-59012018000100003&lng=es&tlng=es.

Flores Sarmiento, O. (2003). Programa de Ahorro de Energía. En Automatización, Productividad y Calidad S.A. de C.V. Administración de la demanda.