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Tesis

Proposal to optimize electricity consumption costs for regulated clients in medium and low voltage - case study: Peru

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Para optar el Título Profesional de
Ingeniera Electricista

Huancayo, 2021

Proposal to Optimize Electricity Consumption Costs for Regulated Clients in Medium and Low Voltage - Case Study: Peru

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***Abstract*—This article presents the results of the savings for electricity consumption obtained from the analysis and application of the tariff options for regulated customers in medium and low voltage in the Peruvian market. The methodology considers the evaluation of 152 consumption profiles of various clients in the commercial and industrial sector, with which simulation sheets were designed for the construction of the load diagrams in order to know the production cycles of the companies. Based on the load diagram and the concepts contemplated in each electricity tariff, the billing scenarios were simulated in the different existing options in order to choose the most convenient tariff for the analyzed company, finding economic reductions up to 23% for the energy payment electrical power as shown in the present study. Finally, a summary table of the rate options associated with the different companies according to their business activity is presented, which will serve as a guide for owners and / or administrators when choosing a rate option.**

Keywords-electricity rates; load profiles; energy; power; medium voltage; low voltage

I. INTRODUCTION

The research carried out is of vital importance for all Peruvian entrepreneurs since a correct choice of rates and an adequate management of your demand will define the success or failure of your company.

The fundamental problem is that the owners of the companies do not know about the rate options that they can access according to their production cycle, and as a result of this ignorance they make excessive payments for the consumption of electricity, adding to this, that the companies Concessionaires provide very limited information in this regard, as well as the limited existence of professionals and / or companies that provide the advisory service to users, who have to assume additional costs for this service if they obtain it. The study presents the analysis and comparative results of the billings in the various rate options (medium and low voltage), identifying the best option that suits the company, taking into consideration that the electricity service is one of the most important costs in its production process. As an example, we can cite that a drinking water company, simply by making a correct selection of its rate option, could reduce its electricity billing costs by approximately $ 20,389 dollars per year.

II. RATE ANALYSIS AT THE SOUTH AMERICA LEVEL

A. South American Tariffs

Table I shows the commercial and industrial rates of each country and a brief comment on each situation.

TABLE I. RATES AT THE SOUTH AMERICA LEVEL

Country	Rate	Comment
Argentina	Tariff 3 - BT <300kW / Tariff 3 - BT> 300kW	It considers the invoicing of Fixed Charge, Charge for Contracted Power, Charge for Acquired Power, Peak Variable Charge, Rest Variable Charge, Valley Variable Charge.
Bolivia	Higher Commercial Rate - C2-GD-BT Lower Industrial Rate - E-GD-MT	Consider a Fixed Charge, consumption ranges 0-100KWh / KW a, m, b and Additional kWh / kW_a, m, b Additionally, CPP and CEPFP.
Brazil	Commercial, Industrial - Conventional Rate	Consider a position in Off-peak, Intermediate and on-peak.
Chile	It has a commercial and industrial rate	It considers Fixed Charge, energy, partial consumption in off-peak hours and current consumption at peak.
Colombia	Commercial, Industrial Rate - Non-residential Sector	Industrial and Commercial - Monomy Commercial, Industrial: in tip and present in off tip.
Ecuador	Commercial, Industrial Rate Low Voltage with demand (BTGD), Medium voltage with Hourly demand (G7 / MTDH);	The billing of power and energy is considered, in addition it is considered hourly periods of: 07h00 to 18h00 6:00 p.m. to 10:00 p.m. 22h00 to 07h00

	Medium voltage with demand (G7 / MTD)	
Paraguay	Commercial, Industrial Rate	The tariff charge is considered reserved power, Excess reserved power, HP energy, HFP
Peru	Medium Voltage (MT2, MT3, MT4) / Low Voltage (BT2, BT3, BT4, BT5)	It is considered a fixed charge and the Rates are dependent on peak hours and off-peak hours, both in energy and power.
Uruguay	Triple Hour Rates - Medium and Large Consumers,	It considers a fixed charge, rates for consumption ranges in flat and peak hours and rates in M.C. and G.C.
Costa Rica	Industrial and Commercial Rate	Consider peak and off-peak energy and power billing
El Salvador	Commercial and industrial rate	Consider peak and off-peak energy billing, a distribution charge.
Panama	Commercial, Industrial Rate	Consider a fixed charge, billing for maximum energy demand at peak and off-peak hours.

Source: Osinergmin - international rates, IV quarter report.

From Table I, it is observed that the countries of South America have similar rates and consider consumption in the peak and non-peak periods (valley), where the price of energy and power differ, if a replica of the work is carried out adjusting to the model of each country, they would have additional information that would contribute to the reduction of electricity costs for their companies.

B. *Importance of Research and Application in Commercial and Industrial Companies*

The novelty of the research is to understand the importance of analyzing the consumption diagrams of the companies to identify the best rate option in order to optimize their operating costs for a lower payment for electricity consumption according to their production.

III. MATERIALS AND METHODS

For a correct analysis, it is recommended to know the production process of the company: production schedules and / or operation of the machinery, size and power of the equipment.

For the study carried out, the following parameters were taken into account:

A. *Charge Factor*

It allows to measure the efficiency of the use of power, in the study carried out it was observed that Peruvian companies have a load factor between 0.1 and 0.6 on average, which indicates that the consumed power is not used properly and therefore it is carried out a payment for an untapped power[1].

B. *Efficient Use of Energy And Power*

It is vitally important to understand that the maximum demand registered in the month is considered for the billing of the generation and distribution power, and in the latter, the maximum demand is considered for a space of 6 months, which is why it is essential planning the operation of equipment in order to make efficient use of power and energy [2], inadequate administration of electrical energy will lead to an economic deficit in the industry. It is important to understand that "efficiency is a relationship that seeks to obtain the same benefits or outputs with fewer inputs"[2].

C. *Power Factor*

Improving the power factor helps to reduce reactive energy, it is important that the employer understands that a low power factor forces him to make a payment for reactive energy in his electricity bill, which is why it is recommended that in case of Bearing in mind this fact, a capacitor bank should be installed in order to improve said factor and therefore reduce the payment of reactive energy [2].

D. *Load Diagrams*

The load diagrams will make it possible to know the production cycle of each company according to its commercial activity, and based on this propose various alternatives to optimize the payment of the electric power service.[3]

E. *Hourly Periods*

It is vital that the investor knows that their consumption in the peak hour period is more expensive than in the off-peak hour period, and for this they must know that:

- Peak hours: 6:00 p.m. to 11:00 p.m.
- Period of off-peak hours: Rest of hours of the day.

In addition to knowing that according to Osinergmin resolution No. 206-2013-OS / CD, it indicates that in the Peruvian case, Sundays, calendar holidays, and extraordinary holidays do not have peak hours, the same that should be used by the entrepreneur to produce more at a lower price.

F. *User Rating*

The user rating is extremely important since it determines the cost to pay for the consumed power, specifically in the MT3 / MT4 and BT3 / BT4 tariffs, why? Because depending on the result of the user qualification, if he obtains a score ≥ 0.5 he qualifies in the present in rush and if it is <0.5 he qualifies in off-peak hours, in this way when the user qualifies in peak hours, the specifications are applied rate of peak hours where the power is more expensive than the off-peak period, then the formula for the user's rating is presented.

$$\frac{\left(\frac{Active\ energy\ in\ number\ of\ peak\ hours\ (month)}{number\ of\ peak\ hours(month)}\right)}{Maximum\ demand\ (month)} \quad (1)$$

G. *Considerations of the Period of Operation of the Machinery*

For a correct analysis, it is necessary to know specifically the details of the company, especially the production process, working hours and / or operation of the machinery, taking into consideration that the productive activities must be planned to optimize the least use of power. according to its demand[4], this in order not to increase payments in the generation and distribution power.

H. *Know the Rate Rule in Detail*

Knowing the standard of rate options - Osinergmin Nro. 206-2013-OS / CD, is of vital importance, in order to select the best option that allows us to obtain the maximum business

benefit; It should be noted that the standard considers the same billing concepts for low voltage tariff options (BT2, BT3, BT4), and their equivalents in medium voltage (MT2, MT3, MT4).

IV. RESULTS

The results obtained from the investigation are shown below:

A. *Analysis of Load Diagrams for the Construction of Consumption Patterns*

From the analysis of the consumption profiles, it has been possible to identify the load diagrams for each type of company, getting to know their production cycle in the different time periods, both in the off-peak and peak hours, knowledge that it will serve to identify the best rate option; Below are the representative load diagrams of some companies analyzed:

In "Fig. 1", the load diagram of a health center can be seen, where it is visualized that the maximum demand during the peak hours and off-peak hours are similar.

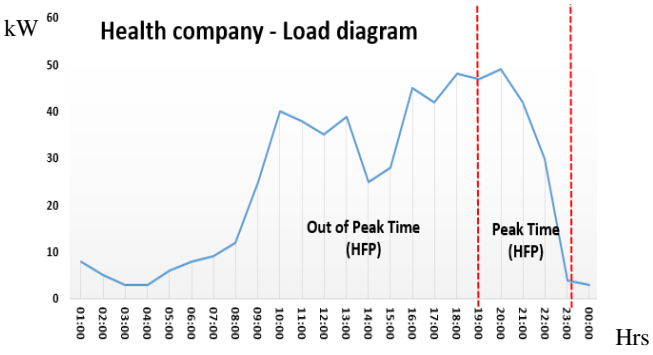


Figure 1. Load diagrams - Business sector, Health companies.
Source: self-made.

In "Fig.2", the load diagram of a water company can be seen, where it is visualized that the maximum demand occurs in the off-peak period at the time the water pump motor operates.

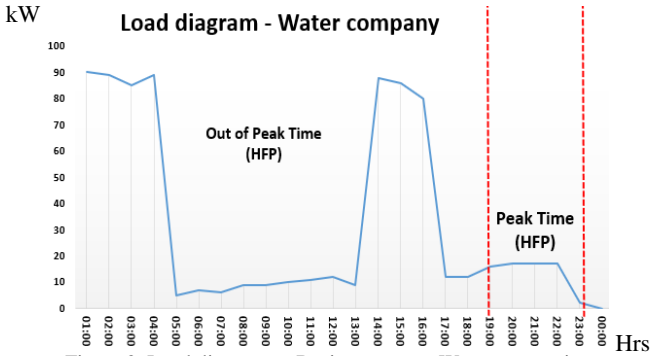
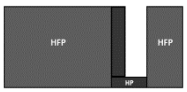
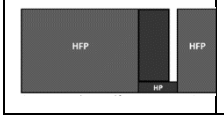


Figure 2. Load diagrams – Business sector, Water companies
Source: self-made.

B. *General Application Criteria*

Next, according to the studies and analyzes carried out, table II shows the criteria for applying the tariff options for medium and low voltage users.

TABLE II. CRITERIA APPLICATION CRITERIA FOR THE PRICE OPTIONS

RATES	APPLICATION CRITERIA
MT2/BT2 	MT2 / BT2 is applied for those companies whose production cycle occurs in the off-peak period and is recommended due to the problems of time lag of the measurement system clock. production is suspended 15 minutes before 6:00 p.m. and restarted after 11:15 p.m. In this rate it is vital to avoid records of the maximum demand in the HP period, which would be a big mistake to do so, since the registered power will be evaluated for up to 6 months for the billing of the distribution power,
MT3/BT3 	MT3 / BT3 will be applied for those companies whose production cycles are carried out in the HFP period and approximately 2 hours out of the 5 hours that the HP period has. It is recommended to monitor the energy consumption at HP in order to avoid qualification as a customer present at peak hours, which, if it occurs, the payment for the power would be higher as established in the tariff schedule.
MT4/BT4 	MT4 / BT4 is applied for those companies whose production cycle is carried out during peak hours and off-peak periods, however, it is recommended to monitor energy consumption at peak hours in order not to qualify as a customer present at peak hours and in this way avoid a higher payment for the power consumed.

Source: self-made

C. *Results of the Analysis of Peruvian Companies*

The results of the analyzes carried out are presented below, the same ones that consider the concepts that are billed in the electricity bills for each option, analyzing 4 cases:

Case I: Drinking water company

The analysis of a user in medium voltage - drinking water company is presented, the same one that is currently billing in the MT3 rate option, however, after the analysis it is concluded that the best option is the MT2 rate, where the billing would be reduced in approximately $ 20,389 dollars per year, so it is recommended to change the rate option. The results of the simulation are shown below:

TABLE III. SIMULATION RESULTS FOR WATER COMPANIES

USER	**Water companies**
RATE	**MT3**
QUALIFICATION	0.0001 **OFF POINT**
CHARGE FACTOR	0.6114
POWER FACTOR	0.9040

CONCEPTS	$	MT2	MT3	MT4
		Facturation	Facturation	Facturation
Fixed charge	$	3.42	3.60	3.60
Connection Replacement and Maintenance Fee	$	6.66	6.66	6.66
Total Active Energy	$/ / KWh			3,712.62
Active Energy Peak Hours	$/ / KWh	0.12	0.12	
Active Energy Hours Off Peak	$/ / KWh	3,516.04	3,516.04	
Street lighting	$/	100.22	100.22	100.22
Reactive energy	$/ / KVARh	117.37	117.37	117.37
Power Use of Distribution Networks				
Present pointed	$/ / KW	0.14	0.00	0.00
Present off-peak	$/ / KW		886.99	886.99
Excess Power Use of distribution networks in HFP	$/ / KW	838.14		
Active Generation Power				
Present pointed	$/ / KW	0.33	0.00	0.00
Present off-peak	$/ / KW		1,194.87	1,194.87
SUBTOTAL	$	4,582.43	5,825.87	6,022.33
IGV	$	824.84	1,048.66	1,084.02
TOTAL IN DOLLARS	**$**	**5,407.27**	**6,874.53**	**7,106.34**

Source: self made

Case II: Health Company

The analysis of a user in medium voltage - health company is presented, the same that is currently billing in the MT4 rate option, however, after the analysis it is concluded that the best

option is the MT2 rate, where the billing would be reduced in approximately $ 12,883 dollars per year, so it is recommended to change the rate option. The results of the simulation are shown below:

TABLE IV. SIMULATION RESULTS FOR HEALTH COMPANIES

USER	Hospital
RATE	MT4
QUALIFICATION	0.5656 ON POINT
CHARGE FACTOR	0.5597
POWER FACTOR	0.9852

CONCEPTS	$	MT2	MT3	MT4
		Facturation	Facturation	Facturation
Fixed charge	$	3.42	3.60	3.60
Connection Replacement and Maintenance Fee	$	6.66	6.66	6.66
Total Active Energy	$/ / KWh			10,222.57
Active Energy Peak Hours	$/ / KWh	2,062.28	2,062.28	
Active Energy Hours Off Peak	$/ / KWh	7,972.31	7,972.31	
Street lighting	$/	100.22	100.22	100.22
Reactive energy	$/ / KVARh			0.00
Power Use of Distribution Networks				
Present pointed	$/ / KW	2,162.69	2,760.26	2,760.26
Present off-peak	$/ / KW			0.00
Excess Power Use of distribution networks in HFP	$/ / KW	435.08		
Active Generation Power				
Present pointed	$/ / KW	5,082.97	5,642.12	5,642.12
Present off-peak	$/ / KW			0.00
SUBTOTAL	$	**17,825.62**	**18,547.45**	**18,735.43**
IGV	$	3,208.61	3,338.54	3,372.38
TOTAL IN DOLLARS	$	21,034.23	21,885.99	22,107.81

Source: self made

Caso III: (Low voltage)

The analysis of a user in low voltage - radio broadcasting company is presented, whose current rate is BT4, after the analysis it is concluded that the best option is the BT3 rate, where billing would be reduced by approximately $ 235 dollars per year. The simulation results for the low voltage options are shown below:

TABLE VI. SIMULATION RESULTS FOR RADIO BROADCAST COMPANIES

USER	Radio company
RATE	BT4

CONCEPTS	$	BT2	BT3	BT4
		Facturation	Facturation	Facturation
Fixed charge	$	3.42	3.60	3.60
Connection Replacement and Maintenance Fee	$	2.03	2.03	2.03
Total Active Energy	$/ / KWh			330.63
Active Energy Peak Hours	$/ / KWh	203.73	203.73	
Active Energy Hours Off Peak	$/ / KWh	764.27	764.27	
Street lighting	$/	100.22	100.22	100.22
Reactive energy	$/ / KVARh	0.00	0.00	0.00
Power Use of Distribution Networks				
Present pointed	$/ / KW	719.32	681.80	681.80
Present off-peak	$/ / KW		0.00	0.00
Excess Power Use of distribution networks in HFP	$/ / KW	0.00		
Active Generation Power				
Present pointed	$/ / KW	460.48	324.50	324.50
Present off-peak	$/ / KW		0.00	0.00
SUBTOTAL	$	**2,260.07**	**2,086.16**	**2,102.79**
IGV	$	406.81	375.51	378.50
TOTAL IN DOLLARS	$	2,666.88	2,461.67	2,481.29

Source: self made

Taking into consideration the maximum demand and the amount of energy consumed, an analysis is carried out to evaluate the convenience of migrating to a medium voltage rate option, the results of which are shown in table VIII, with the MT3 rate being the best option where it is obtained a reduction in billing of approximately $ 6,836,727 per year.

For the change to a tariff option in MT it is necessary to make investments in a distribution substation, for the case study it would have a cost of approximately $ 41,000 dollars which includes the investment of the project and the cost of operation and maintenance, evaluation that is carried out for a 25-year horizon, based on the useful life of the substation, which is why, in order to evaluate the viability of the project, the economic flow analysis was carried out, the results of which are shown below.

TABLE VII. SIMULATION RESULTS FROM LOW TO MEDIUM VOLTAGE

USER	Radio company
RATE	BT4
QUALIFICATION	0.7242 ON POINT
CHARGE FACTOR	0.6826
POWER FACTOR	0.9820

CONCEPTS	$	MT2	MT3	MT4
		Facturation	Facturation	Facturation
Fixed charge	$	3.42	3.60	3.60
Connection Replacement and Maintenance Fee	$	6.66	6.66	6.66
Total Active Energy	$/ / KWh			310.81
Active Energy Peak Hours	$/ / KWh	192.93	192.93	
Active Energy Hours Off Peak	$/ / KWh	702.70	702.70	
Street lighting	$/	100.22	100.22	100.22
Reactive energy	$/ / KVARh			0.00
Power Use of Distribution Networks				
Present pointed	$/ / KW	190.95	201.66	201.66
Present off-peak	$/ / KW			0.00
Excess Power Use of distribution networks in HFP	$/ / KW	0.00		
Active Generation Power				
Present pointed	$/ / KW	448.79	412.19	412.19
Present off-peak	$/ / KW			0.00
SUBTOTAL	$	**1,645.67**	**1,619.97**	**1,635.14**
IGV	$	296.22	291.59	294.33
TOTAL IN DOLLARS	$	1,941.89	1,911.56	1,929.47

Source: self made

TABLE VIII. ECONOMIC FLOW SIMULATION RESULTS

DISCOUNT RATE USED	12%
TIR	15%
VAN ($)	7734.84
PAY BACK (YEARS)	6.17
BENEFIT / COST	1.21

Source: self-made

In the economic evaluation it is observed that the TIR is 15% higher than the discount rate applied to the project (12%), the VAN is positive and that the investment recovery period is 6.17 years, from which, the The company would benefit from this decision, which is why it is recommended that the user migrate to the MT3 rate option in medium voltage.

D. Business Recommendations According to Their Economic Activity

From the analysis carried out on the load profiles, it has been possible to identify and group consumption patterns for each business sector and its corresponding most convenient rate option, the same as shown in table VIII. To guarantee the greatest benefit of the rate option, Investors are recommended to take into account the consumption criteria indicated in table II for each rate option.

TABLE IX. BUSINESS RECOMMENDATION ACCORDING TO THEIR ECONOMIC ACTIVITY

RATES	BUSINESS RECOMMENDATION ACCORDING TO ECONOMIC ACTIVITY

MT2/BT2	Molineras Carpenters Cabinetry Hospitals	Bakeries Water company Schools (primary / secondary)
MT3/BT3	Financial Entities Private clinics	Universities Water companies Public / Private Institutions
MT4/BT4	Casinos Cinemas	Nightclubs Restaurants

Source: self made

V. Discussion of Results

To reduce energy billing costs, it is vital to know the production cycles of each company, as well as the Peruvian regulations on rate options, and based on this knowledge, business recommendations are presented for the application of rate options in MV and LV. For those users whose production cycles occur in the HFP period, the most recommended option is the MT2 / BT2, being a condition to meet that the maximum demand in the HP period must be at most up to 10% of the maximum demand for the HFP period, thus reducing the payment for generation and distribution power. Regarding the MT3 / BT3 rate option, it is recommended for those users who have consumption in the HFP period and part of the HP (2 hours approximately between 6:00 p.m. and 11:00 p.m.), in these rate options it is recommended to Entrepreneurs did not accumulate a greater amount of active energy in the HP period, with the aim of having a user qualification as a customer present in HFP and thus making a lower payment for the power as established in the tariff schedule.

Finally, for users who have a constant production during the day (both in the period of HP and HFP), the best rate option is MT4 / BT4, recommending that entrepreneurs avoid a greater record of active energy consumption in the period of HP in order to qualify as a customer present in HFP, with the objective of reducing the payment of the consumed power.

VI. Conclusions

In order to reduce the billing of their electricity consumption, companies must make a correct tariff choice, the same one that is achieved through a correct evaluation and analysis of their consumption diagram. The results shown in table VIII will serve as support to investors, who will be able to choose their rate option according to the business sector to which they belong. A correct administration of the load factor, power factor, as well as achieving the qualification as a client present in HFP for the MT3 / MT4 / BT3 and BT4 options allows you to pay a lower amount for the power consumed. Finally, for the MT2 and BT2 options, it is necessary to avoid consuming power in HP, in addition to taking advantage of Sundays and national holidays to maximize production, taking into consideration that those days do not consider HP periods.

VII. Recommendations

1.To achieve the reduction of the invoicing for the consumption of electrical energy it is necessary to know in detail the productive process of the company, the production and / or operation schedules of the machinery, the sequence of entry of the equipment to meet the demand.

2.Understand that in these rate options the thought of "light that you turn off, light that you do not pay" does not apply as they are binomial rates, since you pay for the energy and power consumed in a disaggregated way, where the power to pay is the highest power recorded by the measurement system in a period of 15 minutes, once this power is used, it must be used to the maximum in the production process.

3.It is necessary to schedule schedules for the operation of machines and equipment, in order to make efficient use of power, the objective is to attend production with the least power possible.

References

[1] M. O. Abdullah, L. P. Yii, E. Junaidi, G. Tambi, y M. A. Mustapha, «Electricity cost saving comparison due to tariff change and ice thermal storage (ITS) usage based on a hybrid centrifugal-ITS system for buildings: A university district cooling perspective», *Energy and Buildings*, vol. 67, pp. 70-78, dic. 2013, doi: 10.1016/j.enbuild.2013.08.008.

[2] A. Trianni, E. Cagno, y S. Farné, «Barriers, drivers and decision-making process for industrial energy efficiency: A broad study among manufacturing small and medium-sized enterprises», *Applied Energy*, vol. 162, pp. 1537-1551, ene. 2016, doi: 10.1016/j.apenergy.2015.02.078.

[3] E. Giacone, S. Mancò, y P. Gabriele, «Energy Management Techniques for Small- and Medium-Sized Companies (ESDA2006-95808)», *J. Energy Resour. Technol*, vol. 130, n.º 1, mar. 2008, doi: 10.1115/1.2835614.

[4] O. A. Barboza, «Hourly Load Forecast Automation in the National Interconnected System», *Revista Científica de la UCSA*, vol. 1, n.º 1, pp. 4-14, dic. 2014.