BINOMIAL TARIFF: AN ALTERNATIVE MODALITY TO BRAZILIAN LOW VOLTAGE CONSUMER DRAWING ON THE LOAD FACTOR TO SEGREGATE ITS APPLICATION RANGES

Lorena C. Borges dos SANTOS
CPFL Energia – Brazil
lorena@cpfl.com.br

Jairo Eduardo De Barros ALVARES
CPFL Energia – Brazil
jairo@cpfl.com.br

Rafael de Oliveira GOMES
CPFL Energia – Brazil
rafaelgomes@cpfl.com.br

Carlos C. Barioni de OLIVEIRA
Daimon Engenharia – Brazil
barioni@daimon.com.br

Cristiano da Silva SILVEIRA
Daimon Engenharia – Brazil
cristiano@daimon.com.br

Denis ANTONELLI
Daimon Engenharia – Brazil
denis@daimon.com.br

ABSTRACT

Since 2016, low voltage end-consumers supplied by voltages lower than 2.3 kV (73% of the energy consumption market in Brazil) has no more obligation to be charged in the monomial tariff modality.

This paper describes a proposal for the implementation of binomial tariff for low voltage consumers. The proposed modality has the objective of: (i) guaranteeing a fair allocation of costs of the grid, reducing potential cross-subsidies; and (ii) introducing a stabilizing effect on distribution companies' B-segment revenue against strong market reduction scenarios as well as the avoiding distortions due to current tariff structures in the existing monomial structure.

The methodology was developed through a R&D project sponsored by CPFL Energia, which holds four distribution companies responsible for the supply of 9.4 million customers in Brazil.

In addition, Brazilian Electricity Regulatory Agency (ANEEL) opened last December a public hearing to discuss the regulatory impact analysis of some alternative binomial charging. This paper compares its proposal with one of ANEEL's alternative, which considers a fixed cost differentiated by number of phases and consumption ranges.

INTRODUCTION

The construction of an adequate tariff structure is based on the equilibrium of the relations of the economic agents involved, either by the guarantee of financial return to the monopolistic companies, or by the definition of efficient and modicity tariffs to the consumers. A correct tariff signalling allows the best use of the electrical systems in the short and medium term horizons, allowing the mapping of trends in the long term [1].

On the other hand, deficient tariff structures can cause various losses to society and industry agents, such as the occurrence of cross subsidies, inefficient effective rate of return for monopoly companies, the overtaxing of certain market segments and the insertion of cross subsidies and disincentives to the market efficient use of electrical systems [2-4].

El Hage, Couto and Ferraz [5] highlight the role of the regulatory agency in establishing simple and transparent tariffs, whose results do not only reflect efficiency gains of the system, but also make their decisions more defensible to society.

According to Pindyck and Rubinfeld [6], regarding the relations between the consumers and the concessionaire, once the information is not obtained with respect to the new tariffs or the quality of the service or product offered, the market or the proposal offered cannot operate efficiently. However, the inefficiencies resulting from information failures can be eliminated through better communication and negotiation among the parties involved.

In the context of asymmetric information, North [7] says that tariff regulation assumes the crucial role of trying to curb possible abuses of monopoly power, to solve the tensions among allocative, distributive and productive efficiency, to introduce efficient induction mechanisms, transparency and the provision of benefits to consumers who decide to volunteer for a new tariff program.

From the point of view of regulation, a successful charging is the one that, in general, has the following main objectives:

- prevents prices from being below costs (including return);
- avoids excess profits;
- enables administrative agility in the process of defining and revising tariffs;
- prevents misallocation of resources and inefficient production;
- establishes non-discriminatory prices to consumers.

Low voltage (LV) end-consumers supplied by voltages lower than 2.3 kV represent 73% of the energy consumption market in Brazil.

A new paradigm in the distribution companies (DisCos) networks' operational context was set by the LV consumer allowance to generate its own energy with the aim to reduce its consumption through a compensation mechanism (net metering).

Certainly, the creation of a binomial tariff, devised by John Hopkinson [8], is, on its own, relevant. A consumer who chooses to install a distributed generation system, and has financial benefits due to it, must know, in advance, even in the role of consumer, what are the costs of his responsibility in using the DisCos networks in which he is connected.

It is a fact that this same consumer will continue to dependent on his connection to the DisCos network, either for those instants whose generation will be greater than his own consumption or simply when there is no generation. In addition, consumers will continue to use the metering equipment, call center and many other services regarding his energy consumption use. Even if there is a minimum consumption in a fixed amount to be paid monthly, it should be clear to him that the volumetric method of collecting this minimum consumption, in kWh, does not guarantee the necessary revenue for DisCos to cover their capacity use costs.

Due to that, the most sensible suggestion for an adjustment would be to derive from the volumetric calculation of energy prices costs that relate to the capacity and operation of the systems. A prior analysis of how to proceed such actions should be based on the real possibilities of rapid and simple implementation of new tariffs, without any link to the accomplishment of change of meters or new legislative changes.

Until August 2016 [9], when it was revoked, there was an obligation to charge the LV consumers in the monomial tariff modality [10].

Since then, the Brazilian electric sector has been discussing the tariff modality which best equate the expansion of Distributed Energy Resources (DERs) and the balance of the DisCos required revenue, in order to guarantee the remuneration of both the CAPEX and OPEX of the distribution network without the requirement to replace all meters, as most of the meter park in Brazil does not allow the mentioned adjustment.

METHODS

In the actual monomial modality, Group B revenues is tied to energy consumption, creating risks in the recovery of the revenue required for both the investments and the costs of operation and maintenance of the distribution network.

In order to construct the proposed modality two mains premises were considered to:

(i) guarantee the remuneration of the physical structure of the grid as well as its associated operating costs; and,

(ii) minimize the implementation impact to the consumers.

To do so, it is stipulated that the binomial tariff invoice should be equal to the monomial tariff invoice.

The binomial tariff separates the revenue from volume and transportation of the energy sold, guaranteeing the correct DisCos' remuneration for the operation and investments.

The collection of the tariff components should be segregated in energy and demand, as proposed in Figure 1.

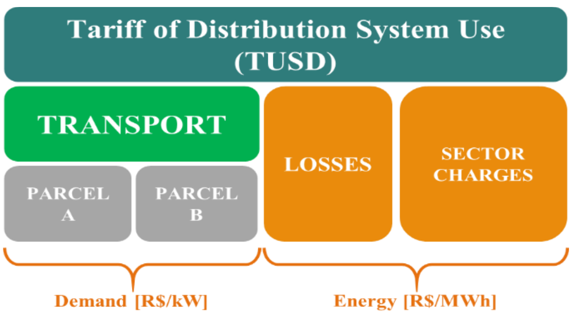

Figure 1 – Tariff of distribution system use (TUSD) proposed segregation

Revenues from the distribution service (Parcel B) are apportioned among the tariff subgroups based on capacity marginal costs (CMC).

The capacity cost expresses the responsibility for the expansion of the distribution system situated upstream of its point of connection for a typical consumer. Each consumer-type will have a capacity cost per tariff position given by the sum of the capacity costs of the station at each voltage level upstream of its connection point.

Considering that the electrical system is dimensioned to support the maximum power demanded by the loads, the methodology proposes to look for the responsibility that each consumer-type has in relation to the maximum demands of the type networks.

The CMC determination of the consumer-types of each voltage level, given in R$/kW, allows the calculation of the theoretical revenue that will provide the preliminary vertical structure of Parcel B. This revenue is obtained by multiplying the maximum demand of each consumer-type by its Marginal Cost, by tariff position, totalizing the values by voltage level. Thus, each voltage level will be responsible for a portion of theoretical revenue, and the percentages of revenue per voltage level in relation to total theoretical revenue establish the preliminary vertical structure.

What is proposed is that LV demand reference tariffs is defined to maintain the EV already defined for the energy reference tariff. In other words, the challenge is to define a demand reference tariff, in R$/kW, equivalent to energy, in R$/MWh, as presented in Equation 1.

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$$Invoice\ LV_{monomial} = Invoice\ LV_{binomial}$$

$$E \cdot TUSD_{en(transp+losses+s.charges)} = D_{max} \cdot TUSD_{dem(transp)} + E \cdot TUSD_{en(losses+s.charges)}$$

$$E \cdot TUSD_{en(transp)} = D_{max} \cdot TUSD_{dem(transp)}$$

Where:

E = consumed energy LV, in $/MWh;

D_{max} = maximum LV consumer demand, in $/kW; and

$TUSD_{en(transp+losses+s.charges)}$ = TUSD energy tariffs regarding Transport, Losses and Sector Charges

$TUSD_{dem(transp.)}$ = Demand tariffs regarding TUSD Transportation.

Equation 1 – LV demand reference tariffs basic premise

Since the maximum demand recorded, due to the unavailability of meters installed in the consumer units, with these measurement records, is not known, what is proposed is that it is determined, based on the load factor of the respective subgroup and consumption range, obtained in the charge characterization studies at the time of the tariff revision, as proposed in Equation 2.

$$f_l = \frac{D_{average}}{D_{max}} = \frac{E}{D_{max} \cdot \Delta t} \longrightarrow \boxed{D_{max} = \frac{E}{f_l \cdot \Delta t}}$$

Where:

f_l = load factor of the respective subgroup and consumption range;

$D_{average}$ = average LV demand of the respective subgroup and consumption range; and

Δt = time regarding the demand calculation period.

Equation 2 – Maximum demand proposed calculus through load factor

By replacing maximum LV consumer demand of Equation 2 into Equation 1, it is obtained the demand reference tariff of Transport TUSD, as shown in Equation 3.

$$TUSD_{dem(transp)} = TUSD_{en(transp)} \cdot f_l \cdot \Delta t$$

Equation 3 – Demand reference tariff of Transport TUSD

The new tariff structure, proposed on a binomial basis, in addition to calculating its tariffs properly, presents as the main advance the conception of a minimum value of demand to be charged to each consumer by virtue of their connection to the grid, named Referential Demand (RD). This minimum value should be responsible for the recovery of all revenue of Parcel B and its form of collection was designed in such a way as to hold each consumer accountable according to the load profile he has (represented by the load factor) and the weight he and their peers have in the use of the distributor system (number of consumers and their linked energy market). Besides the benefits to the consumer (reducing the impact at their invoices), the proposal has simple application and minimal impact on the current methodology of tariff structure to define the binomial tariff for group B.

Load factor per consumption range at LV

The calculation of the load factor required to define the demand tariff to be applied to LV consumers is based on the composition of the typical curves and their respective markets for each consumption range, as defined by ANEEL, whose load profile should be studied when carrying out the measurement campaign of inherent in the process of characterizing the DisCos load.

It is possible to determine the values of average demand and maximum demand by consumption range and type of day from the different load typologies for weekdays, Saturdays and Sundays and their amounts of electric energy, measured during the course of the campaign. In this way, the load factor of a specific consumption range is calculated from the load factors, by day types, weighted by the energy measured and extrapolated for the calendar month, considering: working days (22 days), Saturdays (04 days) and Sundays (04 days), as presented in Equation 4.

Low Voltage demand tariff

After calculating of all the load factors by consumption range, the Equation 3 is applied to carry out the calculation of the demand tariff in the TUSD transport parcel. This new demand tariff will ensure equal invoices in monomial and binomial tariffs. This requirement is of extreme importance in the transition process among the forms of charging, since it will be the defining of a market of demand, in kW, previously absent in Brazilian energy regulation.

$$f_{l_{range}} = \frac{\frac{Daverage_{WD}}{Dmax_{WD}}.22.E_{WD} + \frac{Daverage_{SAT}}{Dmax_{SAT}}.4.E_{SAT} + \frac{Daverage_{SUN}}{Dmax_{SUN}}.4.E_{SUN}}{22.E_{WD} + 4.E_{SAT} + 4.E_{SUN}}$$

$$= \frac{f_{l_{WD}}.22.E_{WD} + f_{l_{SAT}}.4.E_{SAT} + f_{l_{SUN}}.4.E_{SUN}}{22.E_{WD} + 4.E_{SAT} + 4.E_{SUN}}$$

Where:

$f_{l_{WD}}$ = load factor of the respective subgroup and consumption range for working days;

$Daverage_{WD}$ = average LV demand of the respective subgroup and consumption range for working days;

$Dmax_{WD}$ = maximum LV consumer demand of the respective subgroup and consumption range for working days;

E_{WD} = energy of the respective subgroup and consumption range for working days;

$f_{l_{SAT}}$ = load factor of the respective subgroup and consumption range for Saturdays;

$Daverage_{SAT}$ = average LV demand of the respective subgroup and consumption range for Saturdays;

$Dmax_{SAT}$ = maximum LV consumer demand of the respective subgroup and consumption range for Saturdays;

E_{SAT} = energy of the respective subgroup and consumption range for Saturdays;

$f_{l_{SUN}}$ = load factor of the respective subgroup and consumption range for Sundays;

$Daverage_{SUN}$ = average LV demand of the respective subgroup and consumption range for Sundays;

$Dmax_{SUN}$ = maximum LV consumer demand of the respective subgroup and consumption range for Sundays; and

E_{SUN} = energy of the respective subgroup and consumption range for Sundays;

Equation 4 – Load factor of each consumption range

The concept of Referential Demand applied at low voltage

Although the equality of invoices in the forms of monomial and binomial charging has been guaranteed for all consumers, a new binomial tariff must fulfill the role of mitigate risks in the recovery of the revenue related to the DisCos' network use, avoiding that it has its economic-affected by either energy billing or the expansion of Distributed Energy Resources (DERs).

It is a priority that the definition of a binomial tariff protects the investments made by the DisCo.
To achieve those objectives, it is set a Referential Demand (RD), using the concept of a minimum amount of demand to be charged to each consumer due to the use of their connection to the distributor networks incrementing the new tariff structure proposed on a binomial basis.
Assuming that a consumer C1 belonging to the consumption range 100-220 kWh of residential subgroup has its maximum demand calculated, according to Equation 2, lower than the value of RD. For billing purposes, this consumer must pay for the RD. On the other hand, a consumer C2 with maximum calculated demand higher than the value of RD will pay for the maximum demand that he demanded of the system.
Therefore, it is characterized that the consumer C2 is signalling a need for expansion and therefore should bear costs higher than the minimum cost established. C1, on the other hand, does not signal the need for expansion.
In theory, this minimum value should be responsible for recovering all revenue from distribution grid use and its basic function is to ensure that each consumer is held accountable according to the load profile (represented by the load factor) and the weight that he and his peers have in the use of the distributor system (number of consumers and their linked energy market).
The Equation 5 shows that the RD calculation can be done by reference to the average maximum demand of all consumers in each consumption range.

$$D_{max_{average}} = \frac{E/_{8760}}{NCU.f_l}$$

Where:
E = active energy measured over a period of 12 months in kWh;
NUC = average number of consumers in the respective consumption range considering the same period of 12 months; and
f_l = load factor of the respective subgroup and consumption range.

Equation 5 – Calculation of Referential Demand

ANEEL's similar alternative – fixed cost distributed by consumption ranges

ANEEL opened last December a public hearing to discuss the regulatory impact analysis of six alternatives to binomial charging.
Among the alternatives into discussion, there is one which comes closest to the one proposed by this article, allocating the portion of capacity of the cost of distribution by consumption bands as a fixed cost.
At ANEEL's alternative, it is defined a fixed tariff, differentiated by consumption ranges, charged in $ for each consumer unit, to cover distribution availability costs (TUSD Transport – Parcel B).
The revenue associated to this distribution availability costs for each consumption range is now divided equally among all the number of consumers of that band, creating a fixed tariff.

RESULTS

A simulation was made with the fourth largest Brazilian DisCo in LV consumption in 2017 (CPFL Paulista) using monomial tariffs approved in that year.

Paper proposal results

It was noted that the new demand tariffs for consumers of the lower consumption ranges are smaller, in accordance with the values of the load factors of their respective ranges.
From another perspective, it means that those consumers who make less use of distribution assets over time should pay a lower tariff than those who, in addition to consuming more, do so for longer periods.
The aggregate result indicates that the average effect perceived by low voltage consumers of CPFL Paulista, in its binomial invoices, is an increase of 0.27%, as presented in Table 1.
The design of differentiated tariffs and Referential Demand by consumption range also provided an attenuating effect when evaluating the maximum individual increases in invoices, guaranteeing reduced average percentage impacts when compared to the average invoices of the ranges.

Subgroup	Range	Average consumer effect (%)	
B1 - Residential	0-100 kWh	-2.19%	-0.69%
	101-220 kWh	-0.37%	
	221-500 kWh	-0.94%	
	501-1000 kWh	-0.88%	
	> 1000 kWh	1.51%	
B2 - Rural	0-300 kWh	1.65%	3.91%
	301-1000 kWh	3.30%	
	1001-5000 kWh	4.69%	
	> 5000 kWh	4.60%	
B3 - Public Service, etc.	0-2500 kWh	6.46%	2.63%
	2501-5000 kWh	-0.92%	
	5001-10000 kWh	-1.14%	
	> 10000 kWh	-1.00%	
TOTAL		0.27%	

Table 1 – Average effect perceived by LV consumers – paper proposal

ANEEL's alternative results

It was noted that the new tariffs for consumers of the lower consumption ranges are higher, since it was not considered how much these consuming units effectively demand of the electric network, not reflecting the values of the load factors of their respective ranges.

Despite the average consumer effect signalize a decrease in the average tariffs, the remuneration associated to use of the physical structure of the grid is not guaranteed. The aggregate result indicates that the average effect perceived by low voltage consumers of CPFL Paulista, in its binomial invoices, is a decrease of 0.99%, as presented in Table 2.

Subgroup	Range	Average consumer effect (%)	
B1 - Residential	0-100 kWh	9.51%	-0.62%
	101-220 kWh	1.46%	
	221-500 kWh	-2.46%	
	501-1000 kWh	-7.06%	
	> 1000 kWh	-9.18%	
B2 - Rural	0-300 kWh	13.92%	5.67%
	301-1000 kWh	7.01%	
	1001-5000 kWh	4.07%	
	> 5000 kWh	1.92%	
B3 - Public Service, etc.	0-2500 kWh	-1.79%	-2.89%
	2501-5000 kWh	-3.91%	
	5001-10000 kWh	-4.03%	
	> 10000 kWh	-3.83%	
TOTAL		-0.99%	

Table 2 – Average effect perceived by LV consumers – ANEEL's alternative

ANEEL's alternative, although segregating consumption by ranges cannot reflect the impact of each consumer on the grid. Since different consumers can present different uses of the network, the costs that they imply to the system are also different, even if both have the same invoice.
Thus, when establishing a fixed cost for all consumers in the same range, the objective of pursuing tariffs more convergent with system costs, achieving greater economic legitimacy, is not reached.

CONCLUSION

The methodology was developed among CPFL Energia, which is responsible for distribution services to 9.4 million consumers in Brazil, and Daimon Engenharia.
The proposed binomial tariff has the objective of introducing a stabilizing effect of DisCos CAPEX and OPEX revenue related to the use of its power grid in the face of strong market reduction scenarios and avoiding current tariff distortions in the current monomial structure. The idealized proposal was guided by the following premises:

i) simplicity and reasonableness, aiming full transparency and reproducibility of calculations;
ii) minimal impact on the current regulatory procedures, guaranteeing full adherence to the current Brazilian regulatory framework;
iii) maintain the modicity, fairness and responsibility of using the network in the definition of supply tariffs.

Given the innovative aspect of charging throughout binomial tariffs, whose construction is quite simple and objective, facilitating consumer understanding, this new tariff structure can be seen as the cornerstone for the Brazilian electric sector to be adapted to the new disruptive technologies. The average effect so far verified on the invoice of low voltage consumers, are considerably low, not presenting themselves as impediments to their actual realization.
The paper presents the results achieved to CPFL Energia, making this proposal an embracing methodology to any Brazilian and worldwide energy distribution companies.
The proposal studied reflects the impact of each consumer on the network, unlike the alternative proposed by ANEEL, avoiding extra charge to the consumers allocated in lower consumption ranges.
Once the collection risks are mitigated, scenarios are seen with greater benefits for consumers, who would benefit from an electrical system better adapted to receive the current and future technological transformations, providing a safe environment for new business on the load side. Hence, for DisCos, regarding the reduction of their risk of exposure to market variations with robust guarantees to obtain the necessary revenue to provide the wire service and greater encouragement in the definition and expansion of actions directed to energy efficiency.

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