Proposition of Alternatives for Microgrid Insertion in Brazilian's Regulatory Context

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***Abstract* – In this paper some issues related to the Brazilians' regulatory context for microgrids insertion were analyzed. Among various issues, those associated to the fixed minimum billable amount and to the conversion of energy credits generated from net metering in different tariffs were assessed. It is presented a suggested solution for the modification of credit conversion due to generation and consumption at different times, as well as a new structure for the distribution costs charged today to clients of a microgrid or to GD costumers. At the end, the authors conclude that the standby tariff can be a good mechanism to stimulate the insertion microgrids, energy efficiency of these and also to the increase of customers with distributed generation.**

***Index terms* – Microgrids, Minimum Billable Amount, Standby Tariff, Cross-subsidy, Peak Electricity Generation**

I. Introduction

The project on which this work is inserted aims to develop a viable model of a microgrid based on distributed micro generation from renewable sources, storage systems and energy management systems. The microgrid has a pilot application in a residential condominium that groups ten residential consumer units and condominium essential services such as surveillance, security and lighting.

The generation resources will represent an installed power of 50 kW, and the energy storage system with lithium-ion technology is sized to meet critical loads of microgrid for a period of one hour islanded, also functioning a dispatchable source allowing economical operation.

The aim of this paper is to present the results in a specific stage of the project, which deals with the analysis of the regulatory context and Brazilian tariff for insertion of microgrids.

After considering the current context of microgrids insertion, modifications and improvements in the regulatory environment and pricing are proposed. These proposals could contribute to a growing and structured insertion of microgrids in the Brazilian market. To validate the proposals, simulations of scenarios were developed.

II. Research development

The economics of microgrids are driven by the incentive provided by tariffs, fuel costs in the case of microgrids that include fuel generators, and by the regulatory and market environment in a general way. Therefore, should be a priority to establish effective mechanisms through which microgrids can exchange energy and services with the network, capturing a significant share of the benefits they provide.

Nevertheless, this problem is more complex than it seems because the economics aspects of microgrids are highly sensitive to tariff details and related agreements. Thus, an incorrect tariff policy can have a negative influence on the microgrid economy. Because many of the benefits are local, quantifying them is not only a technical challenge, but can also result in wrong compensation in some cases: microgrids could be compensated simply by virtue of the peculiarities of the network and not by a problem that the microgrid is actually solving [1].

A. Brazilian energy market

The Brazilian energy market structure divides clients in two different types. The first type is the free client, who is able to choose an energy provider and an energy price. These decisions can be mediated by traders. The other type of client is the captive client, who is not able to choose neither the energy supplier, nor the energy price. The first type of client is charged with an hourly, binomial rate (demand and energy consumption), while the other is charged with a flat, monomial rate (energy consumption).

Clients with distributed generation lower than 1,0 MW can adhere to net metering policy, injecting their generation excess on the grid, and earning credits (in kWh) for the difference between generation and consumption, in case that difference is positive. Those credits can be used in a maximum period of 36 months. Recently, a public audience was held seeking to modify the net metering policy, increasing the allowed generation limits among other changes [2].

It is expected that microgrids can adhere to net metering

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policy and in that case those systems characterized for grouping various clients with different consuming behaviors and diverse generation fonts, could be seen as an only client with a groups of generators that exchanges energy with the grid.

B. Cross-subsidy and standby tariff

If the microgrid buys less energy from the utility, these utility costs must be recovered by other customers [3]. For this reason, other means of recovering such cost by utilities should be founded.

It is important to notice that not all microgrids adhering to net metering policy run out of self generation the same amount of time. For those microgrids with little downtime or infrequent downtime, standby tariffs may represent an appropriate method to recover the fixed costs of the utility, and also reducing the cross-subsidy.

In American states distributed generation has grown significantly, utilities have had to find solutions to this problem. These solutions aims to ensure that the customer with distributed generation or belonging to a microgrid and using network services, pay their fair share by those services offered by the network while still receives a compensation-for the excess of energy it produces [4]. These are shown in TABLE I, together with a comparison between options in order to justify the choice made.

Hence, the choice was guided by the simplest option to be structured, which is the standby tariff, because it allows an experimental implementation. This is the case of the pilot microgrid being designed, with a greater adherence of the parties involved and results more easily perceived. Also, this tariff can serve as an incentive to peak control.

TABLE I

Approaches to solve cross-subsidy

Solution	Advantages	Disadvantages
Redesigning consumer rates in order to better reflect the costs involved. Adoption of demand rates.	Charge a share of the costs of grid services, charging the appropriate portion of fixed costs to microgrids' customers.	Implementing the strategy leads to certain level of complexity: there is a need to change the meters of all captive consumers and to reformulate rates.
Charge microgrid participants for its total consumption under the captive consumer tariff, and separately compensate them for its generation.	Ensures that the network service cost is recovered, while compensates microgrids by their generation surplus.	Higher cost and a complex administration. Gives freedom to choose the generation tariff and may reduce the incentive for to participate in microgrids.
Impose "standby" tariffs to microgrid participants.	Workaround of cross-subsidy. Payment, as fair as possible, of the reserve held by the utility to supply backup service.	Can reduce the payback of the project. The standby service does not necessarily imply additional costs to the utility, if this service is correctly planned.

1) Motivation for using standby tariff in Brazilian context

Currently, if a consumer that owns micro generation consumes less energy than a certain threshold, it will be charged with a fixed minimum billable amount (group "B"[1]) or with the contracted demand (group "A"[2]); regardless of the amount consumed and the generation time.

This situation is shown in Fig. 1, where the fixed standby tariff portion, represented in light purple, generates a shifting in the generation portion. Without that portion, generation would equal consumption, resulting in a zero billable amount. Though, the standby tariff causes an offset in generation, which could be interpreted as a negative amount of credits charged to the consumer at the end of the month.

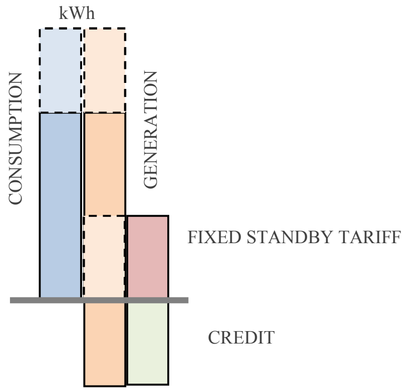

Fig. 1. Fixed standby tariff charged to Brazilian customers

Consequently, the optimization of this tariff is proposed, in order to value differently various types of microgrids that can be regarded as a single customer participating in the net metering policy.

2) Tariff Structure

According to Fig. 2, which represent different situations that could occur during microgrid operation from de utility point of view, the standby tariff should charge situations 1, 3 and 4, because the second situation (supplementary energy) can be charged with traditional tariffs or treated as a part of the net metering policy.

During generation group maintenance, a planned outage will occur, because maintenances can be planned by the microgrid manager, and in those events the microgrid would not be able to meet the load with its own generation. For that reason, the utility will supply the energy required throughout this period. These planned events can be previously notified,

[1] Group composed of consumer units with supply voltage below 2.3 kV, or even, attended at a voltage greater than 2.3 kV and billed in this group, characterized by monomial tariff structure.

[2] Group composed of consumer units with supply voltage equal or higher than 2.3 kV, or even attended at a voltage lower than 2.3 kV from underground distribution system and billed in this group, characterized by the binomial tariff structure.

allowing planning to meet this demand. On the other hand, when a forced outage occurs, the microgrid manager would no longer be able to inform the utility in advance.

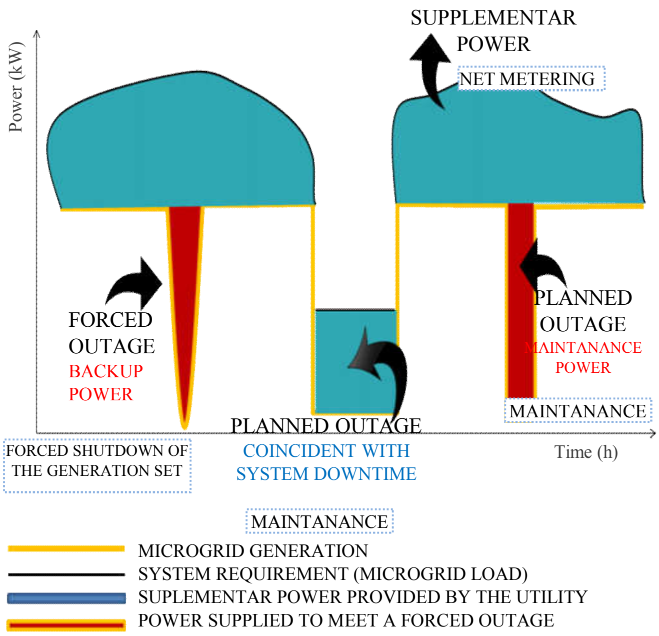

Fig. 2. Different situations in a microgrid

Therefore, is extremely important to minimize those non-planned outages, which are directly related to the generator group reliability.

Given those assumptions, a contracted capacity for forced outage was structured according to the contracted demand weighted by the peak CF[3] and the FOR[4] of the standby client generators, whose values would be provided at the time of contracting the service, also considering the seasonality.

The inclusion of the FOR incentive customers to limit their use of standby backup service, creating a strong price signal to the microgrids behave more efficiently because the lower the FOR, the lower the tariff. Hence, the microgrid may seek alternative solutions in case of forced shutdown, as might be cutting non-priority loads and using storage system to meet the demand of priority loads.

Moreover, by using peak CF, these systems would not only respond to price signals, but also enable strategic dispatch, and may potentially reduce the peak demand of distribution grids, even when the peak from the client and the distributor do not coincide. Flat demand profiles and reliable dispatch are of great potential value for distributors, allowing the delay of substation's infrastructure maintenance.

The inclusion of an incentive for reducing the peak coincidence factor of a microgrid, for example, encourages the efficient use of the grid. With this incentive, the focus will be no longer the shift from consumption to off-peak hours such as the focus of hourly rates, but the decline and even extinction of this peak. This is a more significant incentive than simply shifting from consumption to off-peak time, because it solves the problem permanently.

Summing up, the structure that could be used at first for the Brazilian context is presented in TABLE II.

TABLE II

Defined standby tariff

Tariff Component	Characteristics	Calculation method
Contracted standby capacity for outage[5];	Monthly, yearly correction, peak tariff.	Fixed portion of the tariff, weighted by FOR and peak CF of the generator set.
Demand and energy tariff when standby is used;	Charging occurs only when the service is used (daily basis).	Energy tariff value + exceeding demand value, if necessary.

3) Credit calculation according to the generation time

Another relevant characteristic of the current tariff is the way credits are calculated according to the generation period. A critical analysis of the current formula, shown in Equation (1), points out some issues:

$$Comp[kWh] = E_g \cdot \left(\frac{T_g}{T_c}\right) - E_c \qquad (1)$$

E_g represents the generation excess, E_c the consumed energy, and Tc and Tg are the tariffs defined according to the cost of the kWh in peak and off-peak periods.

Assuming that peak tariff is 0.5 R$/kWh and off-peak tariff is 0.25 R$/kWh, some scenarios can be simulated. According to the factor (Tg/Tc), it is noticed the appreciation of kWh generated or consumed in peak hours. Therefore, the following situations may occur (TABLE III):

TABLE III

Generation and consumption in different tariff periods- - current compensation form

Scenario	Generation/ Consumption [kWh]	Peak Consumption [kWh]	Off-Peak Consumption [kWh]	Credit [kWh]
I	Consumption	0.00	50.00	150
	Generation	0.00	200.00	
II	Consumption	50.00	0.00	150
	Generation	200.00	0.00	

[3] CF (Coincidence Factor) represents the ratio of the maximum demand of any group and the sum of the individual maximum demands of the various components of the group.

[4] FOR (Forced Outage Rate) represents the reliability of the generator set of the microgrid.

[5] Backup and maintenance services were combined under a unique reserve tariff since those services will not be used simultaneously.

When generation and consumption times are different, peak energy has a higher weight with respect to off-peak energy because it is more valuable, and the same should occur for cases where generation and consumption occur both on peak. Though, when generating and consuming in peak time, the formula no longer values the peak surplus the same way, either in consumption or generation. The factor (Tg/ Tc) results in 1, creating the second scenario, when in fact it would be more interesting that the result generated a credit of 300 kWh due to the appreciation of the peak energy generation.

As a result, it is suggested the analysis of equation (2).

$$Compensation[kWh] = B_{op} + \left(\frac{T_p}{T_{op}}\right) \cdot B_p \qquad (2)$$

where B_{fp} is the off-peak energy balance, B_p the peak energy balance, T_p the peak energy tariff and T_{fp} the off-peak energy tariff.

This formula values the energy generated or consumed at peak hours in the proportion of the factor T_p/T_{op}, giving them a value weighing on the off-peak energy. With this formula, the consumer must pay a fair amount for the peak consume and off-peak generation.

The application of this formula gives:

TABLE IV

Generation and consumption in different times – proposed equation

Scenario	Consumption/ Generation [kWh]	Peak [kWh]	Off-Peak [kWh]	Credit [kWh]
I	Consumption	0.00	50.00	75
	Generation	0.00	200.00	
	Balance	0.00	150.00	
II	Consumption	50.00	0.00	300
	Generation	200.00	0.00	
	Balance	150.00	0.00	

Thus, the difficulties previously treated are solved with the proposed compensation.

III. Simulations

A. Simulation inputs

For data analysis, simulations were made considering the use of the proposed modified rates. The main results of these simulations are presented below, performed considering a consumer from the subgroup "A4" (supply voltage from 2.3 kV to 25 kV), with load and generation curves shown in Fig. 3, and adhered to net metering. The consumer may also represent a precursor of a microgrid model in which a number of customers in a region would be seen as a single client in medium voltage.

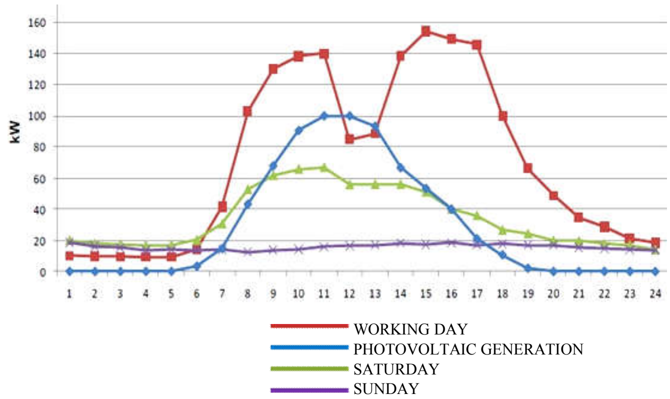

Fig. 3 Load curve of the considered consumer

First, it is important to note that for relevant results (given that the photovoltaic system generates almost entirely in off-peak hours), it was considered that the generator set operates together with a storage system responsible for injecting energy in peak hours, capable of storing 5 kWh for two hours to provide a total of 10 kWh with a discharge time of two hours.

Generation was estimated with help of software PVSyst considering a polycrystalline system of 100 kW located in Fortaleza, Brazil[6]. The equivalence between consumption and generation in different tariffs (in peak hours and off-peak hours) was made using equation (2) proposed.

The simulated scenario is characterized by a period of abrupt fall period in the customer generation; reaching a level below 30 % of the expected value weekly. In such cases the standby tariff is applied due to forced interruption of power generation, which generates an unplanned demand.

For customers of the subgroup "A4", the calculation of the tariff is based on months of dry season (from month 1 to month 3 and month 10 to month 12) or humid (from month 4 to month 9) as shown in TABLE V.

TABLE V

Values in kWh for clients of the subgroup "A4"

		Humid Period	**Dry Period**
Contracted Demand (R$/kW)	Peak	24.31	30
	OP	8.92	15
Exceeded Demand (R$/kW)	Peak	72.93	90
	OP	26.76	45
Consumed energy in outage (R$/kWh)	Peak	0.43	0.46
	OP	0.27	0.34
Monthly Standby (R$/kW)	Peak	13.31	16.43
	OP	4.88	8.21
Consumed Energy (R$/kWh)	Peak	0.37865	0.4
	OP	0.2343	0.3

[6] Polycrystalline technology was chosen because is the most cost-effective technology in Brazil, according to market research.

B. *Microgrid viability*

As a first step, simulations were made using the software Homer Energy, software for optimizing microgrid design, investigating which combination of parameters would allow the viability of the microgrid analyzed.

Considering the parameters mentioned and an unreliable grid, with an outage frequency of 20 times/year, a mean repair time of two hours and a capacity shortage penalty of 10 R$/kWh, the microgrid was formed by the PV system, the Li-Ion battery, a generator used to provide energy during outages, a consumer from the subgroup “A4” and a converter.

A discount rate of 8.34 % was used, according to what is recommended in [6] for renewable energy projects in Brazil, together with an expected inflation rate of 3.50 %, resulting in a real interest rate of 12.06 %.

The results of these simulations, presented in TABLE VI, showed that, for that level of grid unreliability or superior, and with the given economic inputs, the microgrid is viable when compared with the solution of using only the grid to meet the load.

TABLE VI

Values in kWh for clients of the subgroup “A4”

	FV	Li-ION	Gen NG	Ren Frac	Fuel
	100 kW	10 kW	10 kWh	81 %	1.731 L
	0 kW	0 kW	0 kWh	0 %	0 L
	COE (R$)	NPC (R$)	Operating cost (R$)	Initial capital (R$)	
	0.723	719,246	- 842	725,510	
	1.410	746,572	100,340	0.00	

The comparison between the two systems gives the result presented in TABLE VII. The result shows that the microgrid is viable, with a payback of 7.07 years and an internal rate of return of 12.7 %.

TABLE VII

Values in kWh for client of the subgroup “A4”

Metric	Value
Present worth (R$)	27,325
Annual worth (R$/yr)	2,812
Return on investment (%)	14.3
Internal rate of return (%)	12.7
Simple payback (yr)	7.07
Discounted payback (yr)	19.10

This result proves that even with the actual Brazilian economic context that is not favorable for microgrid implementation, some parameters as the level of grid unreliability allow the microgrid viability.

C. *Results achieved*

It is established an equation that relates the standby tariff and the factors CF and FOR[7]: The equation (3) is an initial model and cannot be considered as a final version.

$$ST = CD(h,t).[1-0.5(0.6(1-FOR)+0.4(1-CF))] \quad (3)$$

where CD is the contracted demand and ST is the standby tariff to be calculated[8]. The main idea of this equation is to relate the presented factors with the fixed portion of the tariff (contracted demand in this case), giving different weights to the factor according to the utility interest. If the focus is the dispatch planning, FOR would have a greater weight. On the other hand, if the focus is peak mitigation, CF would have a greater weight.

To show what happens when there is an unplanned output of the generator some weekly downtimes were simulated, such as those shown in TABLE VIII, which represent the scenario in January as an example.

TABLE VIII

Month 1 with the occurrence of generation loss

January	Expected week generation: 2563.25 kWh				
Week	1	2	3	4	**Total**
Generation [kWh]	732.4	2520	366.2	1800	5418.5
Total of expected [%]	29 %	98 %	14 %	70 %	53 %
Days without generation	5	0	6	0	11
Not avoided grid consumption [kWh]	1830.9	0	2197.1	0	Balance:
Peak Demand Excess [kW]	0.7	-	0.45	-	1.1
Off-Peak Demand Excess [kW]	14.6	-	14.8	-	29.4

In the simulation, the amount of excess demand when there was a forced outage was evaluated. The extra cost due to unscheduled outage of the generator, is shown in TABLE IX for the month of January, as well as the total cost obtained at the annual simulation.

TABLE IX

Demand excess when a forced outage occurs

Month	**Peak Difference**	**Off-Peak Difference**	**Peak extra cost**	**Off-peak extra cost**
1	-6.12	-38.40	R$ 550.63	R$1,727.86
Total	9.25	3.92	R$4,010.54	R$ 10,216.45

[7] The higher the FOR is the greater will be the increase in the rate of value, and that, knowing the FC varies from 0 to 1, the higher the index, the greater the increase in value of the tariff.

8 The terms 0.5; 0.6 and 0.4 are arbitrary and serve only as a means of balancing the relationship between the value of the monthly standby tariff and the contracted demand.

Finally, the annual results were analyzed comparing the case of using or not the standby tariff previously proposed. The results for several scenarios are shown in TABLE X, and graphically represented in Fig. 4.

TABLE X

Results of several scenarios using proposed standby tariff

Standby Tariff					
Scenario	FOR	CF	Final balance: batteries + standby	Final balance: batteries + fixed tariff (actual)	Difference
1	13 %	05 %	R$-147,829.4	R$-164,801.3	10.18 %
2	56 %	05 %	R$-156,106.7	R$-164,801.3	05.28 %
3	12 %	72 %	R$-156,232.1	R$-164,801.3	05.20 %
4	72 %	56 %	R$-164,509.4	R$-164,509.4	00.18 %
5	02 %	02 %	R$-145,572.0	R$-164,509.4	11.67 %

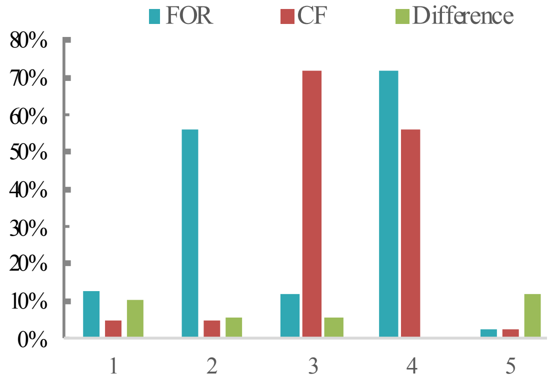

Fig. 4. Graphic results of scenarios

The simulation presented above shows that the final result when using standby tariff results is a lower balance than the case of using the current fixed minimum billable amount. However, it is important to clarify that this difference will be greater the smaller the factors FOR and peak CF. Also, it can be concluded that the tariff:

- Suits to different situations of network use;
- Is lower for those customers who owns generators with greater efficiency;
- Is lower for those customers who avoid using the network on peak time;
- For the limiting case in which FOR is 100 % (no generation) and CF is 1 (the client behaves as a standard client, without avoiding the use of the network in peak hours), the standby fee will equal to the minimum billable amount.

IV. Conclusions

As a main conclusion, it could be said that the regulatory environment and current tariff scenario is already at an appropriate level to allow insertion of microgrids.

However, it was shown the need to address the problem of cross-subsidization, in order to ensure the inclusion of electricity microgrid in the regulatory context and Brazilian tariff with equity. A solution to this problem was proposed, that encourages the prioritization of efficient generation sources within the microgrid, as well as an optimized network usage.

Furthermore, this solution also encourages the efficient use of the grid, focusing on the decline and even extinction of the consumption peak during some hours of the day.

This solution will be tested and implemented in pilot microgrid presented in the introduction, and the environment can be optimized to meet the growing participation of microgrids, which is expected in the Brazilian market in the coming years.

V. References

[1] A. Hyams, “Microgrids: An Assessment of the Value, Opportunities and Barriers to Deployment in New York State” NYSERDA, New York, Technical Report. Jun. 2010.

[2] SRD/ANEEL, “AP nº 26/2015: Revisão das regras para micro e minigeração distribuída,” 15 Junho 2015.

[3] Wood, L., “Value of the Grid to DG Customers”.IEE, Technical Report. Set. 2013

[4] T. Stanton, “Are Smart Microgrids in Your Future? Exploring Challenges and Opportunities for State Public Utility Regulators” National Regulatory Research Institute, Silver Spring, Technical Report. Oct. 2012.

[5] R. M. Firestone, C. Marna e K. M. Maribu, “The Value of Distributed Generation under Different Tariff Structures,” LBNL, Pacific Grove, California, CA, Technical Report. Oct. 2006

[6] K. Rocha, M. B. G. P. S. Gutie, and P. Hauser, “A remunaração dos investimentos em energia renovável no Brasil – Uma proposta metodológica ao benchmark da UNFCCC para o Brasil” IPEA, Rio de Janeiro, RJ, Technical Report. Fev. 2012.