The Regulatory Challenge of Integrating Microgrids in the Brazilian Context

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Abstract - **Sustainability of microgrids depends on a successful business model, enabling technology, and regulation policies. Technical challenges are still significant, but they can be divided and solved in diverse levels with application of existing technology in several ways. However, the regulatory context is vital to incentive microgrids integration into the electricity market. This article aims to explore and categorize different regulatory challenges existing nowadays in Brazilian scenario, in order to identify them, propose possible solutions and encourage investment in microgrids. The main conclusion is that, in general the regulatory environment in Brazil is adapting to include microgrids in the electric system. Though, some regulatory difficulties tend to be solved with the implementation of regulations relating to micro-generation that can be subsequently applied to microgrids and through benchmarking with international experiences from other countries.**

Index Terms— **Brazilian energy market, microgrids, regulatory policies.**

I. Introduction

ENERGY microgrids are a key to future smart grids because they integrate modular energy sources, such as solar, wind, thermal generators and fuel cells, with energy storage devices and both critical and non-critical loads to form low-voltage distribution systems [1].

Before proposing modifications to allow microgrids insertion in the Brazilian regulatory context, it is interesting to review the current regulation, with the aim of clarifying existing policies and remove uncertainty about the participation of microgrids in the system, both for customers and for dealers; in addition to develop preliminary ideas to remove or reduce barriers and obstacles founded.

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Among the regulatory challenges that must be addressed for the development of microgrids in Brazil, the main relate to the definition and management of the microgrid interconnection to distribution and transmission systems, as well as the characterization of a suitable business model. An important aspect of a microgrid is that it can operate in both grid-connected mode and islanded mode, protecting users from grid instability. Therefore, another significant issue is the needing of standards to guarantee the supply of reliable electricity, essential to assure one of the main advantages of these systems.

It is important to point out that microgrids are not currently defined as entities in the existing Brazilian regulation. As a result, the first microgrids to be developed will have to anticipate how the project will be seen and treated by regulators based on its characteristics and offered services.

II. Aspects of Microgrids Integration

A. Microgrid participants

The structure of the Brazilian energy market, presented in Fig. 1, divides clients in two different types. The first type is the free client, who is able to choose who will be the energy provider and 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 price of that energy. The first type of client is charged with an hourly, binomial rate (demand and energy), while the other type is charged with a flat, monomial rate (energy). Microgrids can include on their structure any combination of free and captive clients, and for that reason, it is important to evaluate how different kinds of clients could benefit by integrating microgrids.

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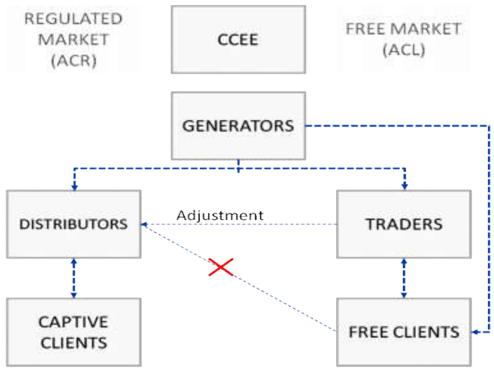

Fig. 1. Simplified structure of Brazilian energy market

B. *Interconnection Rules*

In most of current utilities, including the Brazilian ones, interconnection rules recognize only three power generators connected to the grid[1]: independent producers[2], self-generation[3] and micro-generators. The last ones exchange energy with the distributor through the net metering policy. There are also power producers which have their own generation and do not inject active power in the distribution network.

To have an adequate insertion of microgrids, it will be necessary to create rules that can encompass different types of interconnections that are not currently considered by the distributor. For these systems, the cost of the interconnection has to considerate the ability of acting like a resource that is capable of alternate between consumption and production in short periods of time [2].

C. *Tariff policy for the Brazilian scenario*

For the tariff policies that will allow a better insertion of microgrids in the market, two policies were studied: feed-in tariff and net metering.

Net metering and feed-in tariff policies are relatively robust mechanisms to ensure that customers are fairly compensated for the value of its generation resources. These mechanisms can be adapted to meet current and emerging challenges in order to express more explicitly all services provided to the electrical system by microgrids, while continuing to recognize the value of services provided by utilities. The adoption of each of these policies depends on the context where it will be used, considering factors such as the value of the electricity tariff paid by the consumer, production capacity and installation costs, among others.

According to [3], in recent years in the United States, feed-in tariff policies have been suspended for economic reasons, showing that it could not be built a long-term durable market with this policy. For these reasons, it is interesting to compare both policies from the point of view of real experiences (Table I), giving subsidies to justify the choice made.

TABLE I

Comparison between net metering and feed-in tariff policies

Net metering	Feed-in Tariff
Relationship with the load of the location where the system is installed	
Recommended for systems that generate power equal to or less than the load expected on site.	No relationship between the power generated and the load expected on site
Consumer's behavior	
Net metering ensures that customers seek to match the generation of the system with its energy consumption.	Customers often build excessively large systems to maximize their return. This approach is unsustainable, especially in high-growth markets where costs continue to fall continuously.
Ease of implementation for clients	
It is an easy and simple mechanism to be implemented.	More complex to implement, because a contract is required.
Recommended utilization	
Protects the rights of individual consumers to generate their own energy: the feed-in tariff requires the owner to sell all the energy generated to the network. Therefore, if the energy consumed is greater than the amount paid by the feed-in policy, there will be a loss of revenue. In this scenario, the net metering policy allows to achieve a balance.	For places where the cost of electricity for captive consumers is low, and the cost of energy from renewable generation systems such as photovoltaic generation is high, with a feed-in tariff, the market will not find a balance.
Relationship with government policies	
When interpreting the injection and consumption of network energy as an exchange and not as a process of buying and selling, if the distributor finds that there is loss of income coming from the decrease in power purchase by final consumers; it may avoid the continuance of the policy.	If the government does not set new targets for the feed-in policy once the first stipulated are reached, it may occur that the program is suspended because the goals were achieved, discouraging market growth.
Model structuring facility	
Although is not as economically attractive, the model seeks to be attractive precisely because of the simplicity of its structure compared to the feed –in tariff model	Model with complex structure. Its complexity requires appropriate studies, since the imposition of an incorrect value rates may result in negative consequences.

[1] *Acessantes*: Energy agent with facilities that connect to the electricity distribution system, and groups thereof.

[2] Independent producers: Legal persons or companies working in a consortium that receive a concession or authorization to produce electric power for trade of all or part of the energy produced at their own risk, using the distribution network to accomplish their objective.

[3] Self-generation with surplus sales: Consumers who have their own generation in parallel with distribution system and sell their surplus generation to the distributor or third parties using the network;

Through the analysis of Table 1, it can be concluded that the net metering policy has a greater simplicity with respect to the feed-in tariff policy, because there is no need of taxation and contracts, becoming consequently less dependent on government and changes in the market as a whole. For this reason, it is understood that it will be interesting to continue the use of net metering in detriment of the feed-in tariff policy.

Moreover, the net metering policy is already established in Brazilian legislation, with some years of experience. On the other hand, using feed-in tariff as a policy to incentive the growth of microgrids means having to implement a new policy, which will be also dependent on the economic scenario of the country.

D. Issues in pricing and aggregating microgrids

A power system provider with generation on site can run a power purchase agreement with an individual customer and offer a competitive energy rate. This would be feasible because with appropriate incentives the generation cost of its system can be competitive with regard to price of the package "generation, transmission and distribution" [2].

However, it would be difficult to implement microgrids using resource sharing (i.e. various types of resources that provide electricity to various customers through the distribution system) in this current scenario, because there is a limit on how much each local generator can export. Also, the limitation of generator size could inadvertently limit the type of services a microgrid may be capable of performing, such as voltage or reliability support. For joining net metering policy, there is a capacity limit, currently 1.0 MW of rated capacity [4].

Though, with the creation of the Public Audition 026/2015 by ANEEL (*Agência Nacional de Energia Elétrica*) which aims to provide incentives for the installation of power plants with installed capacity exceeding 1.0 MW belonging to consumers, and to expand the limits of the application of the concept "net metering", it is expected that the maximum power limits of micro-generation units and microgrids using net metering will be increased, enabling the provision of new services to the utility [5]. Several problems are intended to be attacked by the review of Brazilian Normative 482/2012. Among the problems, can be listed: reduction of total time spent for interconnection, the number of systems currently installed in the is still small, the rule does not encompass all renewable sources and fixes very strict limits of power and the use of credits in consumer units of different entitlements but located in adjoining areas is not allowed.

In addition to the problem of generation limits, existing laws limit the captive consumer's ability to buy power from another generator than the corresponding distributor: Law No. 9.074/95 establish a minimum limiting to become free consumer and be able to choose the supplier [6]. For the captive consumer, the distribution company is the compulsory supplier with regulated tariff.

However, a survey commissioned by the Brazilian Association of Energy Traders (Abraceel) held in July 2014 indicates that Brazilians want to have freedom of choice in the electricity sector, in the same way that is done in the telecommunications industry. According to research, 66% of citizens want to have choice in the area, most motivated by the possibility of price reduction in electricity bills [7].

E. Cross-subsidization

Another problem that can be seen is the so-called cross-subsidization [8]: isonomic prices could not adequately recover the costs from utility customers and microgrids or consumers with distributed generation who rely on the distribution system to service reliability, but who buy less utility power than customers who only use the distribution network. As there are fixed costs to be charged, these will be charged at a higher percentage to customers that are not part of a microgrid and buy more energy form the utility, resulting in an unintended cross-subsidy.

Referring specifically to microgrids, this phenomenon also leads to questions about the obligation of the utility to provide an equivalent service for both types of consumers. If microgrids' customers get higher reliability levels, because this is one of microgrids objectives, and increasingly avoid paying their share of the fixed network costs for the maintenance of the utility system, other customers are effectively paying to support premium services to customers connected to microgrids [9].

Though, the benefits of microgrids are superior to the case of distributed generation. These kinds of systems 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 substation's infrastructure be delayed or prevented.

With an encouragement of the efficient use of the grid, achieved, as an example, by including an incentive for reducing the peak coincidence factor of a microgrid, 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.

To explain this idea, let suppose that the hourly rate is intended to encourage consumption during off hours between 17hs and 23hs. Considering that the hourly rate brings the expected result and much consumers respond to the price signal, changing its incentive for off-peak time. In this case, the peak hours will be other than the original, and the distributor will have to modify the original tariff distribution. If consumers respond again to this new sign, we will have a cycle that does not definitely solve the network load over at peak hours.

On the other hand, if an incentive to decrease consumption at peak hours is promoted, the decrease of the coincidence peak factor will be permanent. Of course, this incentive can only be responded by those entities that have the ability and the intelligence to do that, which is the case of microgrids. For that reason, this kind of incentive is relevant and a competitive advantage of microgrids.

F. Barriers for micro-generation

An important barrier for micro-generation is the fact that, for captive clients, the hourly rate that will be implemented soon in Brazil and the net metering policy with photovoltaic generation are mutually exclusive. Even though both of the mechanisms pretend to bring benefits to the grid, the adoption of one of these mechanisms hinders the adoption of the other. The reason is that the typical photovoltaic generation curve, presented in Fig. 2, does not contribute making more customers to benefit from the hourly rate, unless there is a mechanism to move this photovoltaic generation to peak hours, such as storage systems. This is because, as seen in Fig. 2, peak hours are different from photovoltaic peak generation hours.

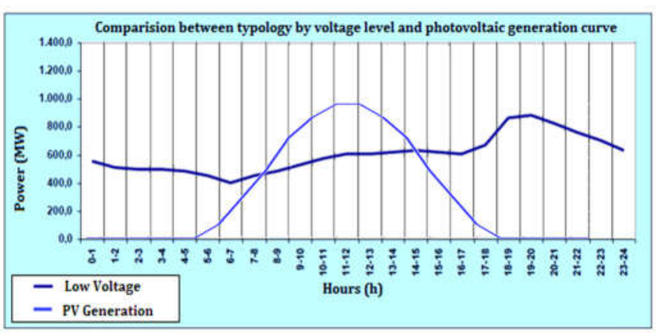

Fig. 2. Comparison between load typology by voltage level and photovoltaic curve

Nonetheless, the integration of consumers with micro-generation in microgrids with storage systems, allows the adoption of the hourly rate. To prove this affirmation, some simulations were made, which results are presented next.

It is important to note that the analysis of the relationship between the hourly rate and micro-generation is made focusing on the case of photovoltaic generation due to the fact that is a trend that is being traced as the inclusion of micro-generation in the Brazilian power system increases. This trend can be seen in the survey conducted by ANEEL aiming to evaluate consumer satisfaction with distributed generation. It was conducted in 2014 [10] and the result is displayed in Fig. 3.

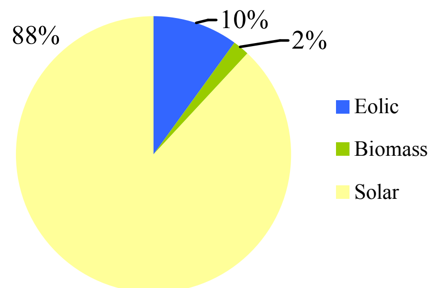

Fig. 3. Result of survey conducted by ANEEL, in 2014

The scenarios were structured in a way that takes into consideration the existence of benefited consumers, non-benefited consumers, and potentially benefited consumers, in terms of changes in their bills by adopting the hourly rate without making any changes in their consuming behavior.

Also, simulations considered consumers in the consumption range above 400 kWh/month, according to the mean curves presented in the reference [11], with their load curve presented in Fig. 4.

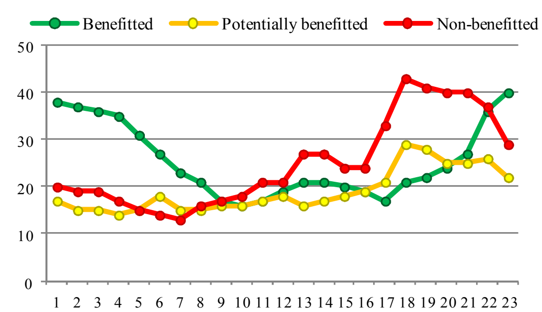

Fig. 4. Load profiles for different types of consumers simulated [11]

The choice of the customers' consumption profile was due to the fact that, as it was shown in the results of the study [11] the group of consumers with consumption range higher than 400 kWh/month is the most representative in terms of proportion of consumers that may benefit if using demand side management strategies. Therefore, it is the group that would benefit the most with the migration to the hourly rate, with reductions of more than 3.23% in the energy bills. This reduction can be improved with a demand side control strategy offered by participation in microgrids.

Briefly, the scenarios simulated are as follows, considering a microgrid with storage system capacity shared between microgrid participants, individual generation, and in some cases, central generation power also shared between microgrid participants.

TABLE II

Simulated scenarios

Scenario	A		B		C		D	
Sub-scenario	AF	AH	BF	BH	CF	CH	DF	DH
Monthly consumption	600 kWh		600 kWh		625 kWh		625 kWh	
Tariff type	FL	HO	FL	HO	FL	HO	FL	HO
Consumer type	NB		PB		B		B	
Storage reserved per consumer	22,5 kWh							
Individual generation	2,0 kW							
Central generation	0 kW						2,4 kW	

where B=Benefited, PB=Potencially benefited, NB=Non benefited, FL=Flate and HO=Hourly.

The first results obtained is that, as expected the consumers that beneffited de most with the adoption of the hourly rate while integrating a microgrid are those considered in the group of benefited consumers. This result can be seen in Fig. 5.

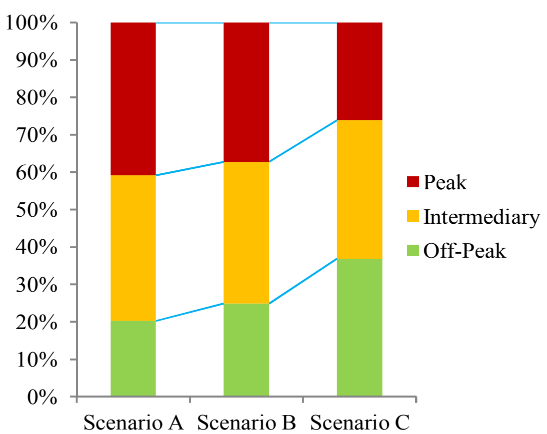

Fig. 5. Comparison of Energy Exchange (%)

Another result of this simulation, which can be seen in Fig. 6, is that the increase of the generation together with the use of a storage system strategy brings an interesting result, which is the augment of energy exchange in the off-peak period with consequent lower purchasing power during peak time, resulting in a flat demand.

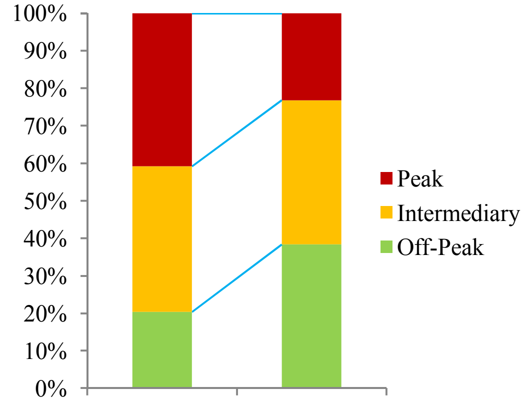

Fig. 6. Comparison of Energy Exchange (%) between scenarios with different generation levels

On the other hand, it is observed in Fig 7 that the energy exchange at R$ is greater in the case of the hourly rate than in the case of fixed rate, for all scenarios. This is because, even if the client did not benefit at first with the hourly rate, the use of storage system to move the generation from off-peak to peak hours helps enabling the benefit. It can be seen that this relationship will be greater the better the consumer behavior is in terms of load profile, and the greater its distributed generation is. This is also a remarkable result; the benefited consumers are the ones who will benefit more from the change of the fixed rate to the hourly rate.

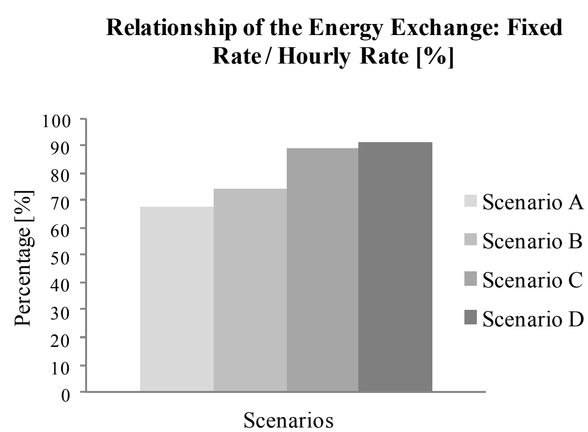

Fig. 7. Relationship of the Energy Exchange: Fixed Rate / Hourly rate [%]

It can be concluded that an alternative strategy of using storage systems to move the generation, increased with a demand side management approach, and the decrease of the proportion between demand and generation, results in an increase of the distributed generation viability when adhering to hourly tariffs. This strategy could be achieved, by an individual consumer, through the participation in a microgrid.

III. Conclusions

The integration of microgrids to conventional power systems need to be done in accordance with current legislation. As in any sector of society, legislation is a key point, setting the standards development and the adequacy of the activity in the energy chain. However, barriers to this practice occur more frequently, and the legislation that encompasses or lack thereof is one of them.

In Brazil, it is noticed that there are several obstacles in the regulation and current pricing that discourage investment in microgrids. Though, these difficulties tend to be solved with the implementation of regulations relating to micro-generation that can be subsequently applied to microgrids, and through benchmarking with international experiences from other countries.

The transition from uniform rates to flexible rates, the guarantee of free access to transmission and distribution networks and the establishment of the net metering policy, can be considered the first steps way to easing the market because it allows consumers to decide the best way to use energy and participate in the system by micro-generation or integrated in microgrids.

It is clear that even if distributed generation and hourly tariff are mutually exclusive at first, participation in microgrids would allow the coexistence of these two strategies, still allowing the profit maximization of the participants as well as generating benefits to the grid, such as improving the load profile, supplying of ancillary services and minimizing disruption costs.

It is expected that the next steps of the Brazilian energy market to follow the European example, where each consumer hires its energy from different suppliers, and in this case, the distributor is remunerated by proper maintenance of the network and a dealer negotiates this energy with the consumer. In this model, a microgrid could be treated as a supplier the consumer would have option to choose.

In general, the regulatory environment in Brazil is adapting to include microgrids in the electric system. However, due to the fact that microgrids are still a recent topic, some regulatory needs that should be resolved, as shown in this article.

However, although Brazil has held the regulation of micro-generation recently, it does not present a significant delay compared to other countries, which already have specific legislation for the micro-generation but, perhaps with a few exceptions, do not have specific legislation for microgrids, needing to use international standards as, for example, the IEEE standards.

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