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Perspectives and Challenges of the Diffusion of Micro and Mini Generation Photovoltaic Solar in Brazil

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Perspectives and Challenges of the Diffusion of Micro and Mini Generation Photovoltaic Solar in Brazil[1]

Introduction

Over the last few years, there has been a process of profound technological changes in the electricity sector, with the most visible feature of this process being the expansionist cycle of renewable and alternative sources in the electricity matrix. Initially, this dynamic was basically linked to the diffusion of wind energy. More recently, photovoltaic solar energy has also initiated exponential growth dynamics. This expansion trajectory is characterized by its diffuse character, with the predominance of micro and mini generation projects in the investments made. In these terms, the hypothesis that solar photovoltaic expansion should be a central element in the transition to electrical systems characterized by the presence of distributed energy resources (RAINERI, 2016) deserves to be pointed out.

Looking ahead, it is possible to envisage the continuity of the expansion of renewable sources and the adoption of measures of demand management, as well as the possibility of using energy storage systems and the practice of the vehicle to grid. In order to deal with this system characterized by the presence of distributed energy resources, the increasing automation of control and operation systems of electrical networks together with intelligent measurement systems is of great relevance.

It is observed with strong consistency the emergence of a new paradigm in the electric sector, of growing opposition to the traditionally current model focused on supply.

In order to make this new technological paradigm feasible, regulatory directives and business models of the electricity sector will need adjustments and reformulations. In the specific case of micro and mini-generation, although their diffusion provides environmental benefits, less need for investments in transmission network expansion and reduction of losses, there are relative costs derived from the need to deal with the increasing intermittence of generation and impacts on the net. More specifically, significant impacts are seen in the scope of the economic and financial balance of the distribution concessionaires due to the reduction of the volume of energy sold in

[1] This study is directly associated with the ANEEL R & D Program linked to the project "Impacts of Distributed Energy Resources for Distributors" executed by GESEL for the Energisa Group. The text seeks to systematize the information and discussions of the kickoff seminar of the project held on 05/20/2016 at FIRJAN, with support from SINERGIA. The elaboration of this study counted on the collaboration of GESEL researchers and students of the Graduate Program of the Institute of Economics of UFRJ: Daniel Ferreira, Eduardo Miranda, Francesco Tommaso, Lorrane Câmara, Max Ramalho and Rafael Cancella. The opinions expressed in this study are the sole responsibility of the GESEL team, not necessarily expressing the positions of the institutions involved.

their markets. The negative impact is due to the predominance of the current logic of the revenue of the distributors being tied to the volume of energy delivered to final consumers. On the other hand, it will increase the need for new investments to adapt and adapt the network to this new technological paradigm.

Within the scope of the Research and Development Program of ANEEL, the project "Impacts of Distributed Energy Resources on the Distribution Sector" executed by GESEL for the Energisa Group, has as its central analytical focus the impacts of the diffusion of micro and mini solar photovoltaic generation On the economic-financial balance of the distribution concessionaires and with the specific objective of systematizing proposals for regulatory innovations necessary to guarantee and support the financial stability of the distributors.

As a starting point for this project, on 05/20/2016 was held at the FIRJAN seminar dealing with perspectives, challenges and impacts for distributors of the dissemination of micro and mini solar photovoltaic generation. The main objective of this discussion paper is to systematize the information, knowledge and discussions held in the event, complemented with accomplished bibliographic researches specialized in the theme.

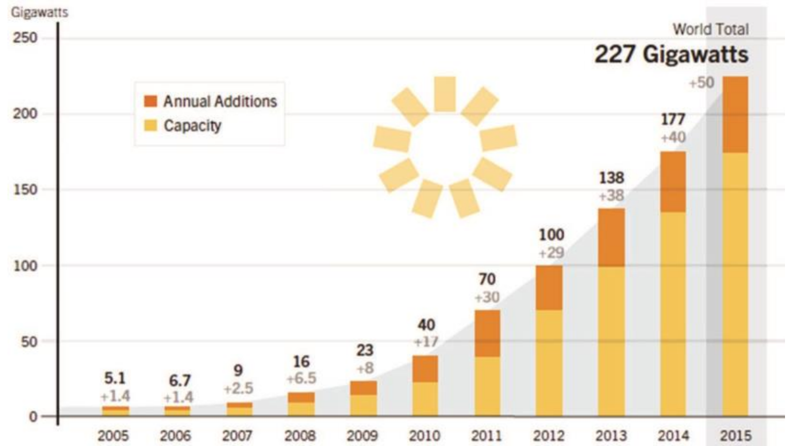
The text is divided into four parts, in addition to this introduction. Initially, the perspectives of micro and mini solar photovoltaic generation are presented. Subsequently, the second part is devoted to the examination of the systemic impacts of the diffusion of small-scale photovoltaic systems. The third part deals with the consequences and impacts of this diffusion on the electrical networks. The fourth part deals with the perverse economic dynamics that make the micro and the mini generation determine a vector of financial economic imbalance in the distributors. Finally, final considerations are made, indicating, in general lines, that the diffusion of micro and distributed mini-generation represents a technological transition that affects different spheres of the electric sector, so that the analysis of the systemic impacts of this process becomes necessary, in the To support the proposition of regulatory adjustments and innovations.

1

Micro and Mini Generation Perspectives

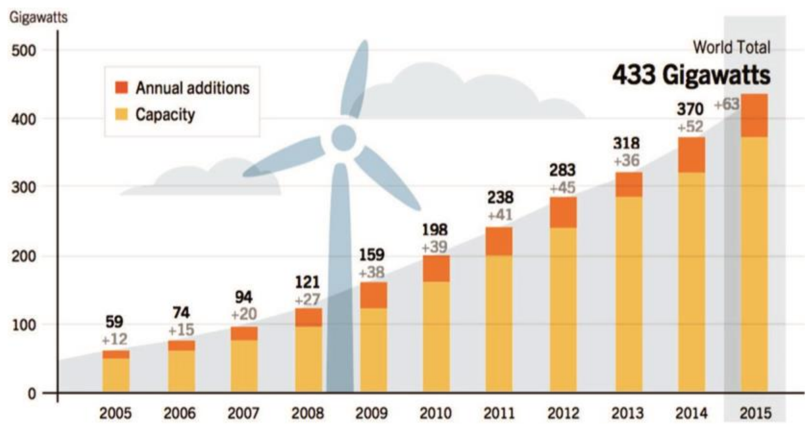
The need to promote a low carbon economy is an important driver for investments in alternative and renewable sources of electricity generation, especially in the more developed countries, given the high predominance of non-renewable sources in the electric matrix. As an illustration of the growing importance of this source, in the period between 2005 and 2015, wind and solar photovoltaic sources expanded, as indicated in graphs 1 and 2.

Graph1 - Global Photovoltaic Generation Capacity and Annual Growth: 2005-2015



Fonte: REN21 (2016)

Graph 2 - Global Wind Generation Capacity and Annual Growth: 2005-2015

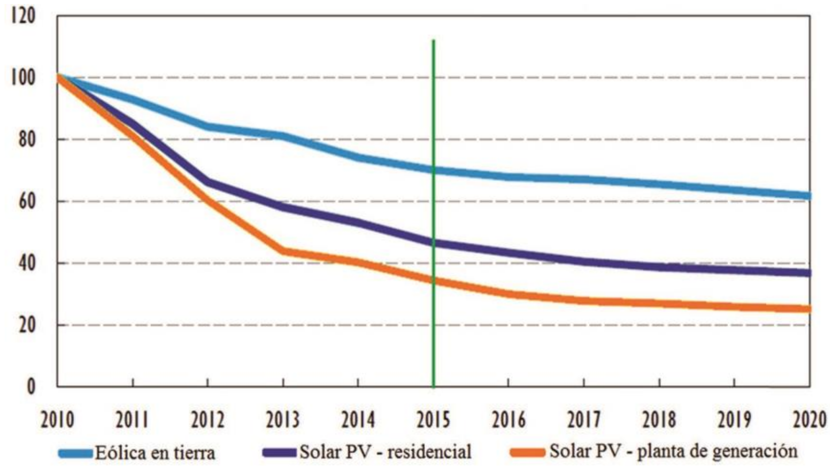


Fonte: REN21 (2016).

This rapid growth process was driven by consistent public policies to encourage these sources[2].
. As a consequence of these incentive measures, gains in scale, industry learning and technological advances have enabled an accelerated reduction in the costs of these technologies, largely explaining their accelerated diffusion. Graph 3 illustrates the competitiveness gains of wind generation and photovoltaic systems.

Graph 3 - Global Generation Cost Ratio for RE: 2010-2020 (2010 = 100)

[2] The implementation of these policies is derived from the need to reduce the environmental impacts of the energy sector, especially those associated with the emission of greenhouse gases. At the same time, it is noteworthy that countries dependent on the importation of large volumes of oil see investment in renewable sources as a means of reducing their energy dependence. It is relevant that in 2004 there were public policies to support renewable sources in 144 countries, contrasting with the number of 44 countries verified in 2004 (REN21, 2014).

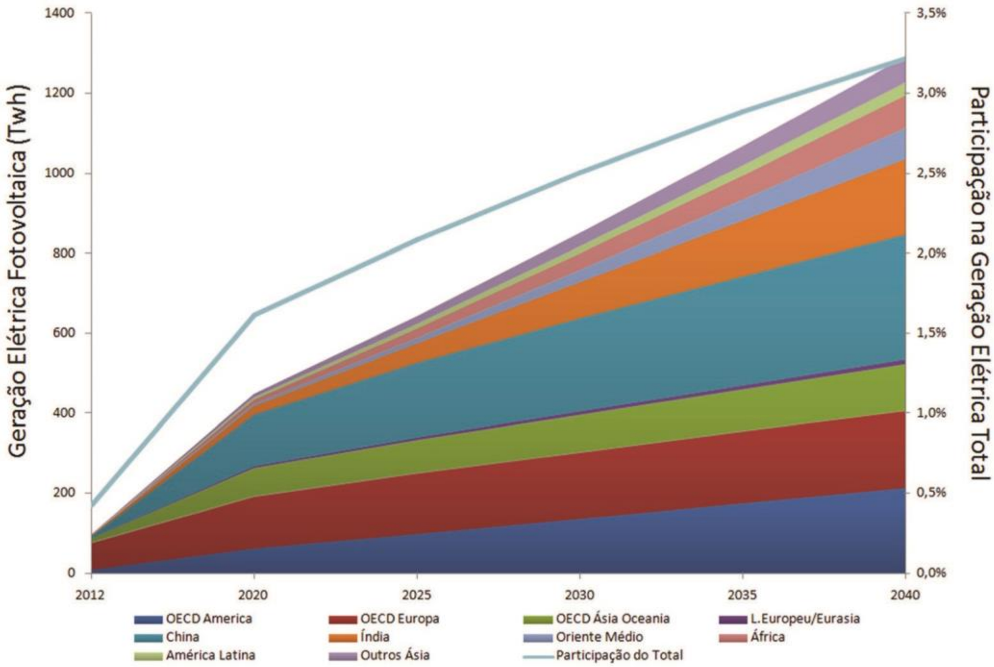


Fonte: Raineri (2016)

Solar photovoltaic generation is characterized by the predominance of micro and mini-generation projects. Despite the issues related to the intermittent nature of solar photovoltaic energy, there are challenges inherent to the presence of bidirectional energy flows. It is observed that the large-scale dissemination of micro and mini-generation imposes great technical, economic and regulatory challenges on the secondary electric sector, largely due to the need for technical adaptation of the electricity grid and the traditional regulatory models used.

It will require a dynamic and strategic dynamic link between the diffusion of new technology, the economic-financial balance between the "old" and the new business and the regulatory route, as the expansion cycle of photovoltaic solar generation will remain along Years. Graph 4 below shows the projected evolution of solar photovoltaic generation up to 2040 for different regions of the world.

Graph 4 - Worldwide production of photovoltaic solar energy by region. 2012-2040 (in TWh and%)

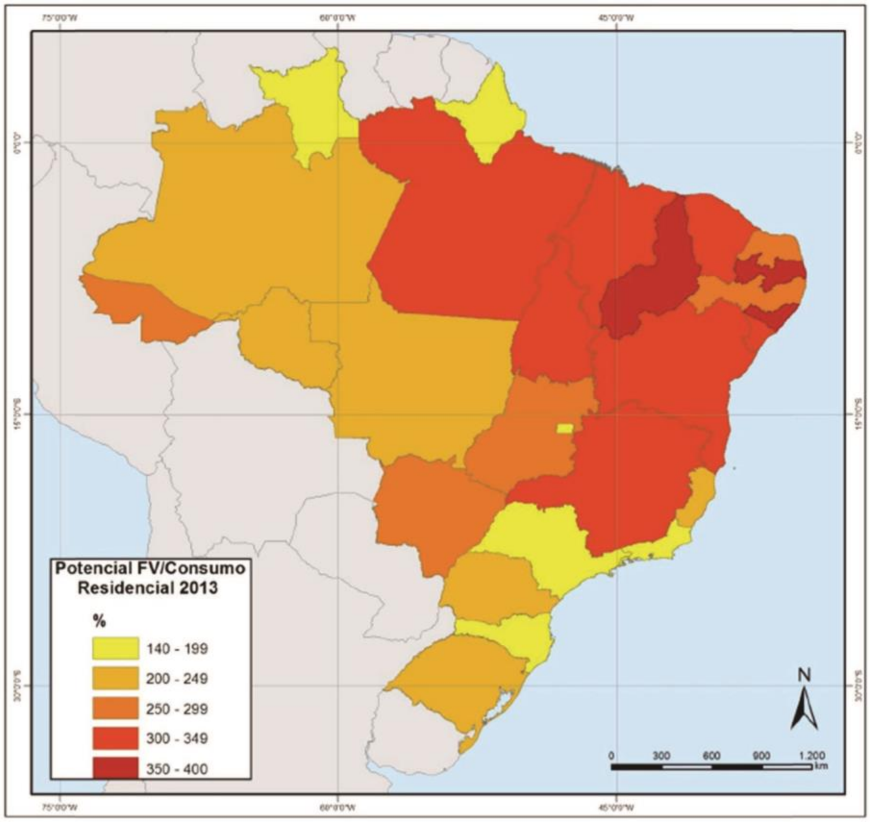


Fonte: Elaboração própria com base em IEA (2014).

As can be seen, in the coming years the expansion of photovoltaic solar generation will be driven by investments in emerging countries, especially China and India. In this context, it should be noted that countries with large solar irradiation, such as countries in the Middle East, Africa and South America, tend to be faced with an exponential growth in photovoltaic solar generation, to a great extent taking advantage of the reduction of Production from gains in the new scale of the production chain, notably driven by China's production chain.

In the Brazilian case, the diffusion process of the solar photovoltaic source is still very incipient, being restricted to isolated systems and R & D projects. However, as can be observed in Map 1, Brazil has a high potential for photovoltaic solar generation. For sizing purposes, this potential is estimated by the EPE in 230% of residential consumption (2014a).

Map 1-Brazil. Technical Potential of Photovoltaic Generation



Fonte: EPE, NT 19/2014

The Brazilian generation of electric energy is mostly of renewable origin due to the predominance of hydroelectricity, making it one of the most efficient electric matrices in the world in this requirement. In this way, the solar photovoltaic source being a renewable source does not constitute an inducing element of investments in the same magnitude verified in other countries with more "polluted" nature and dependent on the importation of energy inputs. In this sense, in Brazil the understanding of the driving factors of solar photovoltaic generation is analyzed by the following points:

(i) Transition to a hydrothermal paradigm, accompanied by the tendency to increase the electric energy tariff due to the more frequent activation of thermal plants;
(ii) The need for high investments in the transmission segment, due to the high distance of the hydroelectric plants and wind farms of the consumption centers, resulting in increased technical losses, higher energy tariffs, and the environmental impact caused by the construction of the Lines;
(iii) Objective of universal access to electric energy;
(iv) High level of non-technical losses due to energy theft, which also exerts a high pressure on the tariff (Shayani, 2010).

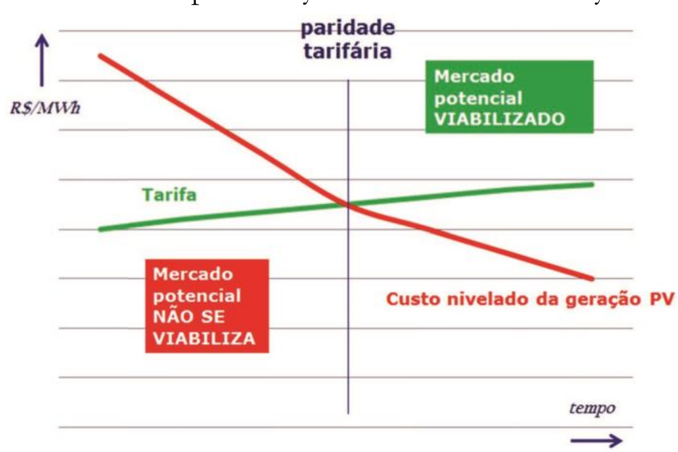
According to EPE (2015), Brazil begins the process of effectively inserting the solar photovoltaic source into its matrix. The EPE highlights the contracting of 891 MW in the auctions conducted in 2014 and estimates that the Brazilian generating park will have a photovoltaic solar power of 7 GW for the year 2024. It is worth noting that utility scale projects will be relevant, especially when implemented hybrid projects Between solar photovoltaic and wind energy[3].

In turn, EPE (2014a), emphasizes the importance of micro and mini-generation to service the cargo over the next few years. Since these systems represent a reduction of the load, they represent the possibility of reducing the need for investments in conventional plants based on the logic and paradigm of centralized generation.

However, in spite of the enormous Brazilian potential for photovoltaic solar generation and the relevance of small scale projects, a determinant aspect for the diffusion speed of micro and mini photovoltaic generation can be translated into the concept of grid parity, which Deals with the economic conditions that make photovoltaic electricity competitive in relation to the electricity tariff charged for the supply through the distributor networks. The grid parity is obtained at the point where the consumer is indifferent between investing in a photovoltaic system or continues to be supplied by the distribution network. (Spertino et al., 2014; Rüther and Zilles, 2010).

Therefore, the attractiveness of investments in photovoltaic systems is a function of the evolution of the costs of these systems and of energy tariffs. Warrior (2016) highlights this relationship from a conceptual point of view through Figure 5.

Graph 5 - Dynamics of Tariff Parity



Fonte: Guerreiro (2016).

According to the EPE, based on the cost projection data presented in Graph 6:

"According to projections of cost reductions, it is estimated that distributed photovoltaic generation reaches tariff parity practically all over the national territory, for consumers served in low voltage, around 2022, while for consumers served in medium voltage (Group A4) tariff parity should become reality only at the end of the 2020s. "(EPE, 2014b, P.221)

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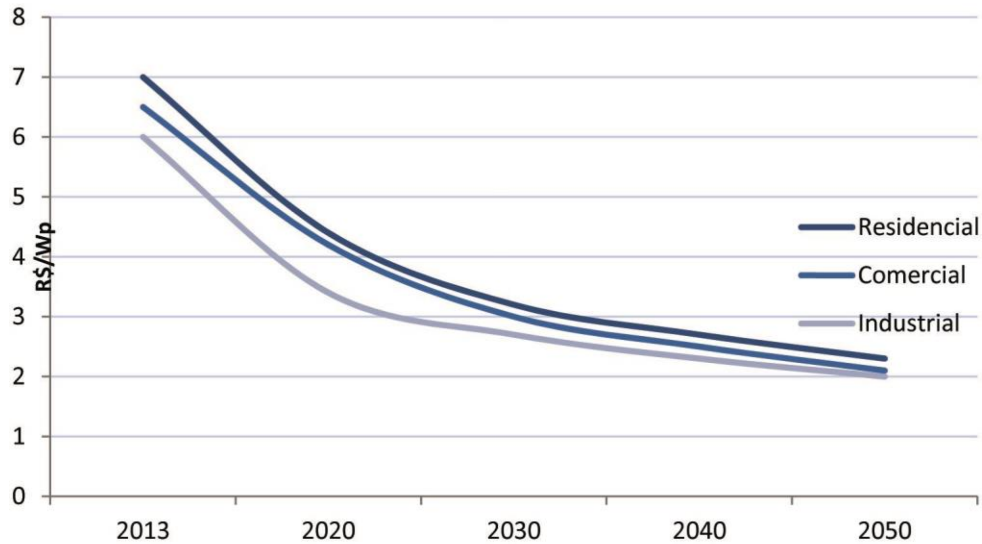
[3] The pertinence of the construction of hybrid parks is derived from the observation that the load curves and the generation peaks of the wind and solar photovoltaic sources are different. Therefore, the construction of plants that combine these two sources optimizes their generation capacity. At the same time, ventures of this type are more competitive due to the dilution of the average costs inherent in the connection and use of the network.

Graph 6 - Perspective of cost reduction of photovoltaic systems: 2013-2050 (R $ / Wp *)



Fonte: Elaboração própria com base em EPE (2014b).

(*) **Wp** (Watt-peak) is the unit of measurement used for photovoltaic panels and means the power in W provided by a panel under specific conditions and reproduced in the laboratory. It is the maximum power that a panel can provide in ideal conditions. "Source: http://www.neosolar.com.br/aprenda/percuentfrequentes

According to Martins (2015), the obstacles to the expansion of small-scale solar photovoltaic generation in Brazil, both in terms of consumer optics and in relation to energy distributors, deserve to be highlighted. Consumer barriers can be summarized as follows:

(i) Financial;
(ii) Institutional and regulatory; and

(iii) Commercial.

And regarding the barriers to be faced by the distributors, the following issues can be highlighted:

(i) Doubts about the role of the concessionaire in the realization of the connection of the generating unit with the electric network;

(ii) Increased grid instability, since distributed generation is composed of renewable sources, which are essentially intermittent;
(iii) Increased complexity of procedures and execution of maintenance, security measures and system planning;
(iv) The dissemination of distributed generation units will reduce the utilization factor of the distribution network and determine an increase in electric energy tariffs; and

(v) Financial deficits in the accounts of the generators, transmission and distribution companies resulting from the increase in the number of microgeneration units.

Within the scope of the public policies of incentive to the Brazilian development of generation distributed from renewable sources, Normative Resolution nº 482/2012 promulgated by ANEEL stands out. This resolution deals with guidelines regulating microgeneration access (defined as a power station with a maximum installed power of 100 kW) and distributed minigeneration (central with installed power between 100 kW and 1 MW) to energy distribution systems, as well as Implementation of a net metering system.

The energy compensation system enables the surplus energy produced by the consumer and injected into the distribution network to represent, in Brazil, a physical energy credit. Credits are used at times when the demand for energy of the consumer is greater than its generation, that is, in the periods where the consumer is acquiring energy from the network, thus constituting a barcode graphic account.

It is important to note that Resolution 482/2012 did not characterize the clearing system as purchase and sale, but as a free loan. According to data from ANEEL, since the publication of the resolution in 2012, in the first quarter of 2016, 2,632 generating plants have already been installed, of which 97.6% of the total projects are photovoltaic solar plants (ABSOLAR, 2016).

More recently, in order to expand the scope and effectiveness of the Resolution, changes were made through the enactment of Normative Resolution No. 687/2015, which came into effect on March 1, 2016, establishing the following modifications:

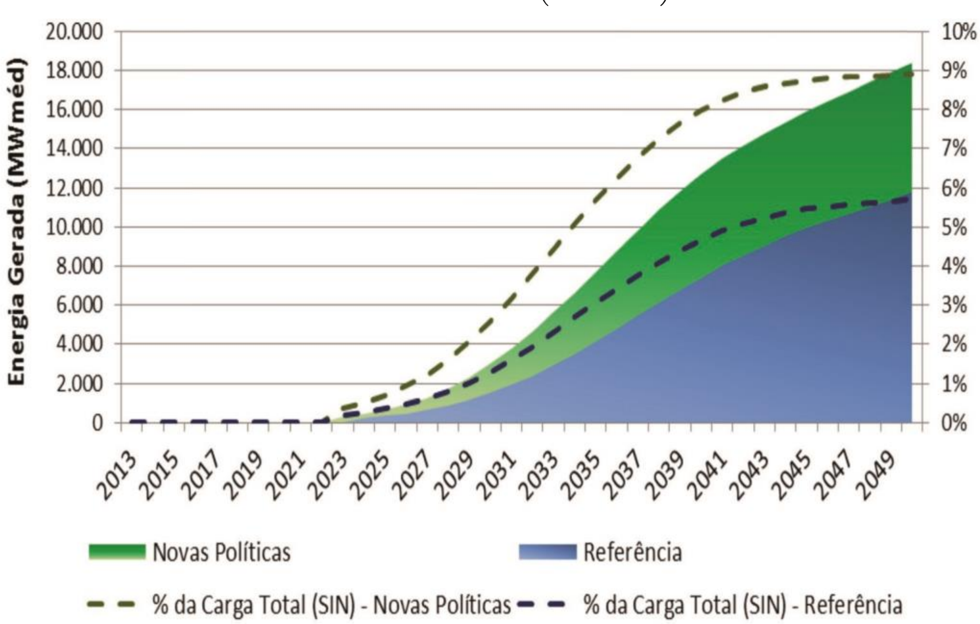
(i) Alters the microgeneration and the minigeration limits from 100 kW and 1 MW to 75 kW and 5 MW respectively;
(ii) Extending the validity of the energy credits accumulated by consumers from 36 to 60 months;
(iii) Creates the possibility of installing distributed generation in condominiums, and the generated energy can be distributed among the condominium owners, in previously defined percentages;
(iv) Creation of the shared generation alternative, in which several stakeholders form a consortium or cooperative and install a micro or mini-unit and use the amount of energy generated for the purpose of reducing the participants' account; and
(v) Changes the necessary procedures to connect the distributed generation units to the distribution network, reducing the requirements necessary to request the access by the consumer, and reduces the maximum time for the distributor to make the connection from 82 to 34 days.

Despite the advances made by the Regulatory Agency through REN 687, the tax question remains controversial. Initially, through CONFAZ (National Council of Finance Policy), through ICMS Agreement No. 6, dated April 5, 2013, the ICMS tax rate was applied on all energy consumed in the month, which did not exempt the volume of energy Produced by the micro or mini generator and injected into the network (ANEEL, 2014), forcing distributors to use total consumption as the basis for calculating the taxes to be paid. The corollary of this form of taxation was a disincentive to the attractiveness of investments in photovoltaic systems.

In 2014, ANEEL (2014) objected to this taxation logic, arguing that taxation should focus only on the difference between total consumption and the energy generated by the micro or mini-generator and injected into the grid. The Agency argued that if the amount of energy produced exceeded the energy consumed, taxes should be calculated on the basis of the cost of availability. In this sense, in response to criticism from stakeholders, and with emphasis on ANEEL's position, Agreement No. 16/2015 changed the rule then in force, becoming optional the collection of ICMS, thus transferring to the state sphere the power to decide For the collection (or not) of the tax. However, 16 states adhered to the new rule, so that in other states the tax issue still represents a discouragement to the diffusion of micro and distributed mini-generation (MGD).

Considering that micro and mini-generation in Brazil have reached a consistent level of regulation, electricity tariffs in the country are at high levels and the tax obstacles are partially equated, investments in photovoltaic systems by consumers connected in the Low voltage network tends to become more attractive. In this sense, EPE (2014b) estimates that distributed solar photovoltaic energy can account for 1.3% of the SIN load in 2030 and 5.7% of the load in 2050. For this, the prospective study, a capacity 10 GWp in 2030 and 78 GWp in 2050. It should be noted that these figures refer to the reference scenario, since in a more optimistic scenario with more aggressive incentive policies an installed power of 118 GWp is estimated in 2050, representing 8.7% of micro and mini solar photovoltaic generation. Chart 7 presents the prospects for the two scenarios.

Graph 7 -Evolution of Micro and Mini Generation Solar Photovoltaic in Brazil. 2013-2050 (MWméd)



Fonte: EPE (2014b)

It can be observed that the diffusion perspectives of micro and mini solar photovoltaic generation are strongly influenced by current regulatory guidelines and possible incentive policies. In this way, it should be noted that, although REN 687 has opened up the possibility of new business models for micro and mini generation, the commercialization of surplus electricity produced in the consumer units remains. For some experts, this factor is one of the great obstacles to the development of this type of generation.

In short, since net metering does not allow the commercialization of surplus energy that is produced, there is no incentive to install equipment that produces more energy than the need for consumption itself.

Guerreiro (2016) points out the liberalization of commercialization as a key factor for the dissemination of the small generation. The author emphasizes that, in preventing the commercialization, the current regulation makes different alternative business models unfeasible. Thus, in many cases, attractiveness is questionable and, as a consequence, exploitation of the potential market tends to be more constrained and time consuming.

An alternative presented at the FIRJAN seminar by several exhibitors would be the creation of a distributed generation market, allowing the negotiation of buying agents with marketers rather than small individual generators, and greater coordination and interaction between micro and mini generators and distributors . The general proposal would be for distributed generators to join a marketer, who would negotiate surplus energy for the free market. The advantage of this proposal is that prices in the free environment are traded freely. In addition, the technical quality of the distribution networks to which these projects connect would be favored through the participation of marketing agents that could more adequately meet ANEEL's technical requirements.

Castro (2016) highlights the importance of the liberalization of the commercialization of surplus generation distributed in the Free Contracting Environment (ACL), presenting a proposal for an alternative marketing mechanism to the electric energy compensation system. In the proposed scheme, the micro or mini generator would have the option to commercialize all the energy injected into the grid, that is, the net energy after consumption. Thus, the amount of energy generated that is currently accounted as physical credit to be compensated later, considering the current energy compensation system, in the model proposed by Castro would be sold to the marketer. In this mechanism the electric energy marketer would act as an aggregator, which would be responsible for the commercialization of the energy generated from a kind of virtual plant, which corresponds to the sum of the surplus energy of several micro and mini generation plants. In this sense, sales of surpluses to marketers would be registered with the local distributor, agent responsible for the commercialization of electricity in the retail market, as a paid service, especially the collection of the measurement of surplus of mini and microgeneration, and aggregation of the measurement According to the negotiations of sale of surplus of micro or mini generators for each marketer. Regarding the wholesale market, the aggregated data (generated by the distributors) would be transferred to the Electric Energy Trading Chamber (CCEE), representing the generation of the virtual mills of each marketer, which would execute energy sales contracts in the ACL , Under the logic of the current regulation [4].

[4] It should be pointed out that the distributors would act as a measurement and data aggregation agent, informing CCEE only the total generation surpluses in its concession area related to each marketer, and would be remunerated for the provision of these services. It would be necessary, however, the definition of specific regulation, aimed at the recognition of new business models to be practiced by the distributors. Castro also points out that the distributor could provide various types of information services and systems aimed at the management of micro and mini-generation by the consumers or marketers themselves. As regards the measurement systems required for the collection and aggregation of measurement data by the distributor, Castro states that those established in REN 482/12 would already meet this need.

2

Consequences of the Micro and the Mini Generation: systemic approach

As discussed earlier, micro and distributed mini-generation tends to become more attractive to the consumer of electricity because of the reduction of their costs of adopting incentive policies in many countries. However, this dynamics of diffusion of photovoltaic solar generation tends to cause significant impacts in the electric sector, being important the systemic analysis of the diffusion impacts of distributed solar photovoltaic generation, which will be the focus of this part of the study.

Figueiredo (2016) points out that the integration of distributed energy resources presents a great challenge, not only from the technological point of view, but also from the economic and political-regulatory point of view. The author stresses that a diagnosis should be made of the systemic benefits of these resources against centralized generation, so that the costs of integrating micro and mini-generation systems into the distribution network should not be neglected. Figueiredo points out that the intermittence of decentralized generation, the need for network reinforcement and adequacy, the question of generation capacity response, product quality and measurement infrastructure are variables that need to be considered in a cost-benefit logic.

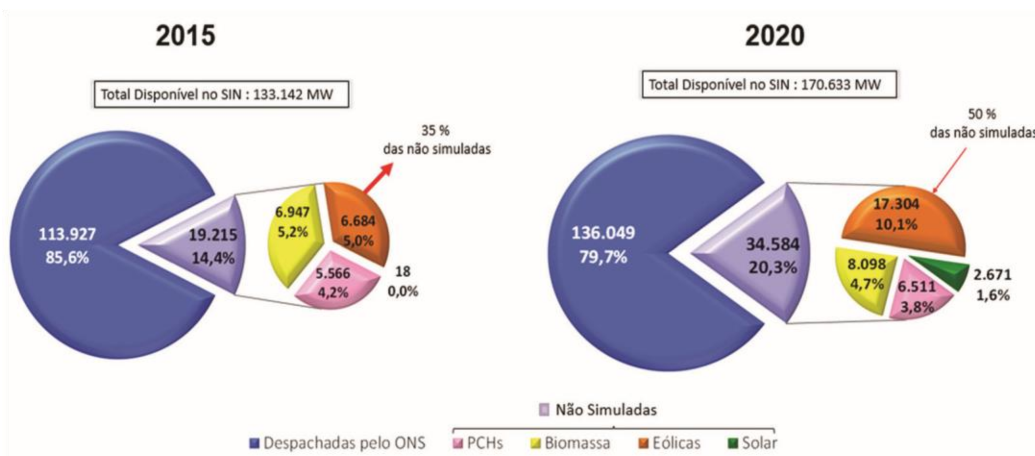
Commonly, environmental benefits are seen as an important motivation for encouraging micro and mini solar photovoltaic generation, notably in developed and emerging countries where non-renewable matrices prevail. In fact, their renewable character and the lesser need for investments in the expansion of generation and transmission network, besides bringing benefits in terms of reducing the emission of gaseous pollutants (both greenhouse gases and local pollutants) and the inherent damages to Transmission infrastructure.

In any case, it is necessary to examine in more depth the effects on the electricity sector. On the one hand, there are benefits derived from a lesser need for investments in generation and transmission network, as well as in reducing system losses. In the Brazilian case, the diffusion of photovoltaic solar generation contributes to the diversification of the electric matrix, which is desirable in a context of reducing the water supply regularization capacity due to the impossibility of constructing new accumulation reservoirs6. At the same time, the diffusion of micro and mini solar photovoltaic generation is cost avoided due to the less need for investments in generation plants. In addition, it helps to control network technical parameters that determine the quality of the supply (eg voltage, frequency, harmonics, reactive power, etc.), especially in a context where the implementation of intelligent networks exists.

On the other hand, there are costs involved that need to be considered, and it must be emphasized that they will affect different agents in the electricity sector in a different way. For example, it is necessary to examine the alternatives to be implemented to guarantee the security and the quality of the supply in a context of increasing participation of intermittent sources in the electrical matrix. In parallel, it is plausible to assume that there will be a need for investments in the network to deal with bidirectional energy flows (Figueiredo, 2016).

The examination of the Brazilian electrical matrix and its perspectives shows the increasing participation of non-controllable sources. The impossibility of constructing new accumulation reservoirs has led to a reduction in the capacity to regulate hydroelectric supply. Graph 8 indicates a strong evolution of wind power, imposing on the ONS - system operator - challenges inherent to the intermittent nature of this source by increasing the portion of generation that is not dispatchable. In this way, solar photovoltaic expansion makes the system even more sensitive to the issue of non-controllable generation. This increase implies a relevant network cost in terms of increasing the technical and operating complexity of the system at the national system level, coupled with a lower generation control. In short, the supply guarantee in energy and electric terms becomes more complex.

Graph 8 - Evolution of Installed Capacity available in SIN. 2015-2020



Fonte: Elaboração própria com base em Arteiro (2016)

6 The new hydroelectric plants will be mainly of the water type and, consequently, the capacity to regularize the SIN will gradually decrease, making the system increasingly dependent on generation complementary to the hydro, especially during the dry season. The expansion of planned hydroelectric installed capacity between 2015 and 2020, only 1% has reservoir. See (Arteiro, 2016) and Castro et al. (2010)

Storage technologies appear as an alternative to attenuate the strong variations in the load curve associated to a system of expressive increase of the participation of intermittent sources[5]. Thus, in moments of great solar generation, every could be stored, attenuating this variation, and

[5] Even disregarding the modern technologies of energy storage systems, it is emphasized that the accumulation reservoirs associated to hydroelectric plants represent a considerable storage capacity by the Brazilian electrical system. In this sense, low levels of intermittent generation would tend not to be a major problem in that these reservoirs could be used in order to give operational flexibility to the system. However, as already mentioned, the wind power source has been expanding at high rates in recent times. Therefore, it does not seem reasonable to imagine that hydroelectric reservoirs will be capable of solving the challenges arising from the penetration of intermittent sources prospected for the next few years.

mitigating negative technical aspects arising from this type of generation [6] (Falcão, 2016). Although the issue of electricity storage is still incipient and its costs are still high, it is necessary to monito the evolution of this technology, since it can contribute to the mitigation of problems inherent in the large-scale expansion of micro and mini-generation[9].
Regardless of the technological advances that will economically make storage systems viable, the intermittent nature of photovoltaic solar generation results in costs for the systems. These costs can be materialized through the reinforcement of the transmission system and / or, mainly, with investments in controllable generators capable of performing the system backup function. In this sense, although the insertion of distributed generation systems tends to reduce the cost of operating the system [7] , it is necessary to consider the implicit costs associated to the adoption of measures that guarantee the security of supply in the presence of high levels of intermittent generation.

Despite the obvious need for the presence of controllable generation plants in a system with high penetration of intermittent sources, it is worth noting that based on established commercial guidelines, energy diffusion does not and does not even allow investments in projects with control, As it compromises the economic viability of existing plants. This is because at times when the photovoltaic power plants are generating, they will move mills that were traditionally shipped. This shift has consequences in the economic and commercial spheres. Even plants that can be dispatched will face lower energy market prices and are unable to make the business viable. This problem has already been experienced in European countries due to the high penetration of intermittent sources in recent years and the solution has been to create capacity markets.

In the Brazilian case, the dynamics are quite different because there is no short-term energy market, but a mechanism for settling the differences determined by the PLD (settlement price of differences). Broadly speaking, the micro and the mini solar photovoltaic generation when reducing the load tend to reduce the marginal cost of operation of the system. However, this signaling underestimates the need for the presence of a park capable of acting as backup and the associated cost.

Nevertheless, within the logic of the Brazilian model of contracting energy through long-term contracts, reducing the load will bring with it a financial risk for the agents. For example, hydroelectric plants that have sold energy by quantity may be subject to water risk and, as a consequence, be forced to liquidate large volumes of money. In turn, distributors may stay on

[6] At the same time, the importance of the implementation of intelligent networks to deal with the challenges of the diffusion of distributed energy resources is emphasized. For this to be possible, it is necessary to address problems inherent in the precariousness of the telecommunications network and, above all, to adopt regulatory guidelines compatible with the modernization of the network through investments in more efficient technologies. 9 ANEEL, in view of the importance of this issue, issued a call for a strategic R & D project in the strategic project category (ANEEL, 2016).

[7] In the Brazilian case, distributed generation is traditionally treated in the models of operation and planning of the Brazilian electric sector as a reduction of the load. Therefore, given a particular configuration of the system, the greater presence of micro and mini solar photovoltaic generation results in a reduction in the marginal cost of operation of the system.

contractors, but the net financial effect will depend on the characteristics of each distributor's energy portfolio.

Concomitantly, although the growing participation of micro and mini-generation companies tends to reduce the asset base of distributors, conceptually understood as network companies, in the long term, it is necessary to emphasize that in the short / medium term they will be required Adaptations in the distribution network to allow bi-directional power flows (Figueiredo, 2016). The need for these reinforcements will depend not only on the characteristics of the previously existing network and the rate of diffusion of the micro and mini generation, but also on the amount of energy generated that will be injected into the network [8] . In any case, it is consistent to say that the diffusion of micro and mini solar photovoltaic generation will impose costs on distribution concessionaires that are not adequately priced by the current regulatory framework[9].

On the other hand, it is necessary to examine with attention and consistent criteria how the diffusion of the photovoltaic solar energy will represent of loss of revenue for companies of the electric sector, especially for the concessionaires of distribution, linked to the loss of market. This is a dynamic problem with implications that transcend the analysis of the financial economic equilibrium of the distributors.

From the perspective of distribution of the costs associated with the diffusion of micro and mini-generation, the tariff applied to those who join this type of generation will be subsidized by those who do not adhere, in a system where the "no roofs" end up paying a share of the cost Of maintenance, and of possible reinforcement of the network, of the "with roofs" (Figueiredo, 2016).

In general terms, the basic premise of the current regulatory model is to remunerate distribution activity based on the volume of energy demanded by consumers. Thus, given the revenue required by the distributor to cover its operating costs and the remuneration of its asset base, a reduction of its market derived from the expansion of the micro and mini solar photovoltaic generation will mean a lower billing than would be necessary to guarantee The economic and financial viability of the concessionaire. This is a problem that would persist until the next tariff review of the distributor. Considering that there will be no major changes in the distributor's cost structure in the short / medium term, the solution adopted by the regulator to guarantee distributing revenue in the face of a scenario of market reduction will be the tariff increase. It is noticeable that this increase in tariffs further strengthens the incentive to migrate to investments in micro and mini solar photovoltaic solar generation systems and, therefore, ends up giving feedback to the process [10].
. This vicious cycle, called "Death Spiral" [11], will be discussed in more depth in Section 4 of this study.

In this process, energy consumers who migrate late will be hampered by the increase in network usage charges. This effect becomes even more socially perverse when income, which is one of the main determinants of the degree of immobility of agents in this process, is considered.

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[8] It is observed that the analysis restricted to the installed capacity can be misleading, being imperative the examination of how much of the energy generated is effectively injected into the network.

[9] The impacts on the distribution network will be dealt with in the next section of this discussion paper.

[10] This tariff increase has the side effect of encouraging consumption reduction, in many cases through the adoption of energy efficiency measures, and the theft of energy.

[11] *Utilities Death Spiral* (Dyner et al., 2016).

In this way, consumers who remained without adopting micro and mini-generation systems would end up subsidizing network access for those who only use it as a battery (Dyner et al., 2016).

In addition, in the scope of the specifics of the Brazilian electric sector, another question to be examined is the treatment of losses, especially non-technical losses. In general terms, the regulator recognizes an acceptable level of loss on which the distributor is entitled to be reimbursed. However, for a given level of regulatory loss, the verification of the reduction of the market derived from the diffusion of the micro and the mini generation will represent a lower reimbursement. That is, in practice, the actual losses of the distribution concessionaire will exceed regulatory losses.

Therefore, a systemic analysis indicates the need to consider all the costs and benefits involved in the diffusion of micro and mini photovoltaic solar generation, and it is relevant that the analysis also contemplate the distribution of these costs and benefits among the different agents. In this sense, the next section of this study will examine the impacts of distributed generation to the network, while Section 4 specifically addresses the economic and financial impacts to the distribution distributors of micro and mini generation.

3

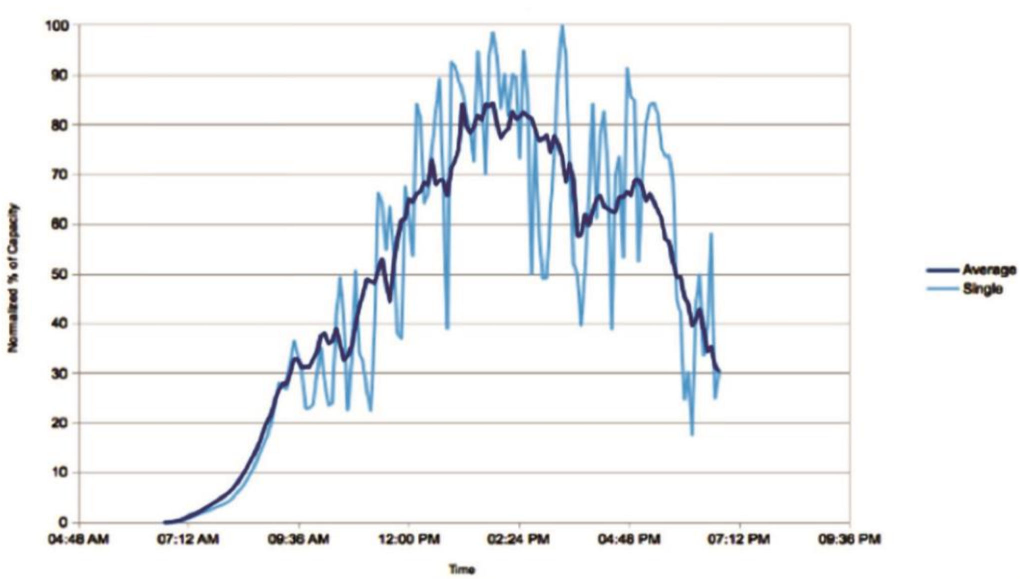
Impacts of Micro and Mini Generation in the Electric network

Traditionally, the Brazilian electric sector was structured based on the generation of energy through large units, with predominance of hydroelectric plants and to a lesser degree conventional thermoelectric plants. Currently, there is a strong tendency to expand the share of alternative sources in the Brazilian energy matrix. The diffusion of these new generating units in the electricity grid leads to a change in the paradigm of generation of the sector, since the wind and solar sources have as main characteristics the intermittence. Consequently, the electric sector undergoes a paradigm shift marked by the following main aspects:

(i) Increasing the variability of generation, as the matrix becomes increasingly diverse;
(ii) Reduced predictability due to the intermittent nature of the energy provided by alternative sources; and
(iii) Reduced dispatchability, since generation from intermittent sources is poorly controllable and the hydroelectric expansion model based on plants with large reservoirs is depleted.

Graph 9 illustrates the effect of intermittence on distributed generation, showing the typical curve of generation of a solar photovoltaic plant. Due to the influence of cloudiness, the output power is unstable and unpredictable, so there is no steady energy associated with solar generation. On a sunny day, the curve approaches the upper theoretical limit, while on heavily overcast days, derisory generation values are recorded (Guerreiro, 2016).

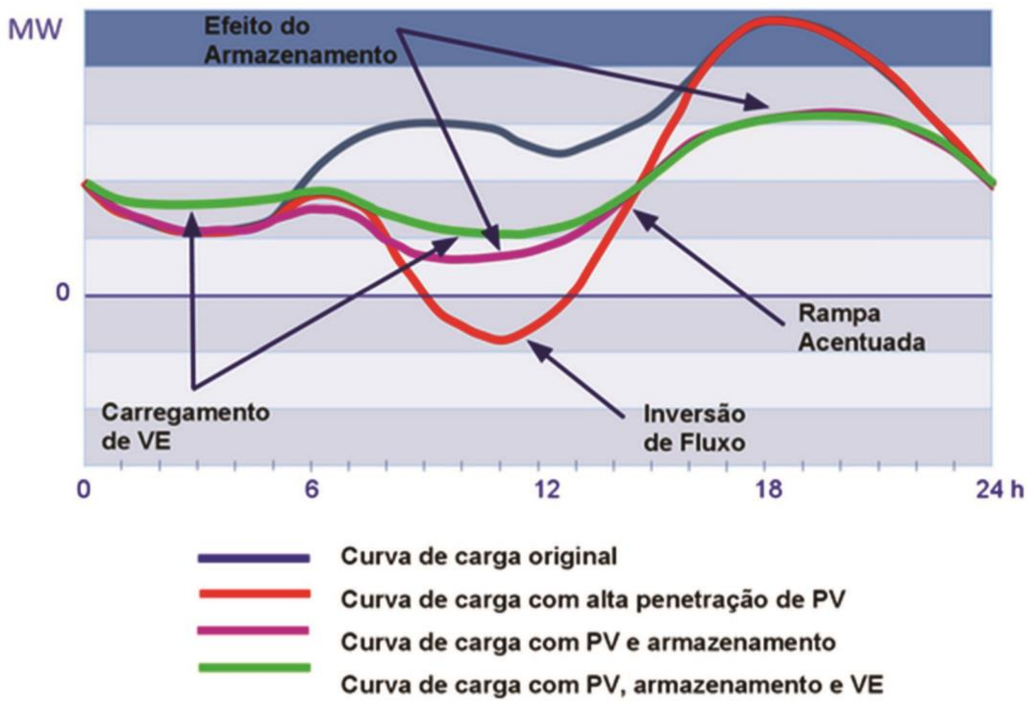
Graph 9 - Solar generation on a typical day (% of normalized capacity).



Fonte: Guerreiro (2016).

It is observed that the main impact of distributed microgeneration is the distortion of the load curve, as shown in Graph 10. Photovoltaic generation, depending on the intensity of sunlight, works at its optimum around noon. In a scenario of widespread diffusion of this technology, the larger generation of photovoltaic cells from late morning to early afternoon significantly detracts from the load curve. In this context, where there are large numbers of consumers producing their own electricity, unconventional oscillations that will determine a characteristic of the new paradigm.

Graph 10 - Technical impact of the MGD on the daily load curve in different scenarios (In MW).



Fonte: FALCÃO (2016)

Eventually, it is possible to imagine an inversion in the power flow, so that microgeneration feeds the power grid. On the other hand, as the energy density on the photovoltaic panels decreases, consumers are again requesting electricity from the grid, so that an abrupt rise in the load curve occurs during the afternoon. Therefore, the insertion of distributed photovoltaic generation implies a non-smooth loading curve. Instead of gradual variations, peaks and valleys of demand are observed. This is not desirable from the operational point of view, as it presents difficulties in controlling voltage, raises transmission losses [12] , worsens the quality of the electricity supply service and requires a greater idle capacity of the system.

[12] A possible negative impact of distributed generation is, paradoxically, the increase in losses. Originally, one of the advantages of distributed generation is the proximity to the load and, consequently, the reduction of the transmissive losses. However, with a possible reversal of the power flow direction, the situation reverses. In order to know quantitatively the relationship between the gains provided by the proximity to the load and the losses related to the inversion of the flow, it is necessary to study the load cycle as a whole.

As mentioned earlier, a technical solution that has the potential to significantly soften this deforming effect[13]. is the expansion of energy storage technologies. Technological advancement and cost reduction by allowing increased storage capacity will allow the intense solar flow of 12h at other times of the day, avoiding underconsumption at midday and, at the same time, reducing the slope of the load curve between The afternoon and evening hours. In a technologically more promising scenario for the diffusion of distributed generation systems, the fleet of electric vehicles will contribute to the smoothing of the load curve.

The transmission of the electric power from the generating plants to the point of loading is carried out through the transmission and distribution systems. Because they work with high voltages and carry large amounts of energy, transmission systems already have sophisticated control and protection systems. The situation is different for distribution networks. The distribution network systems are divided into:

1. Sub-transmission or distribution in high voltage, where it is commonly operated at 138 kV. The sub-transmission feeds the substations, in the output of which will connect medium voltage lines;
2. Medium voltage distribution (feeders), which typically operates at a voltage of 13.8 kV. These are, for example, urban air lines interconnected by poles;
3. Low voltage networks, with an electrical voltage that can vary between 110 and 440 V, are those which, also affixed to the same concrete posts that support the medium voltage networks, are located at a lower height. Low voltage networks carry electricity to households and small businesses through the connection branches (ABRADEE, 2015).

The further away from the transmission system, the less control there is on the distribution lines. The sub-transmission system, for example, currently has a satisfactory level of control. Medium voltage systems, on a smaller scale, while low voltage distribution has few protection and control features.

The paradigm shift derived from the diffusion of distributed generation should inexorably generate investments to improve protection and control mechanisms, especially for the medium and low voltage networks to which the mini and micro generators will be connected (FALCÃO, 2016). In

[13] There are several existing technologies for energy storage. However, currently, reversible plants represent practically all of the global installed capacity, with approximately 130 GW. This number equals 99% of the total installed power of energy storage technologies in the world (GUERREIRO, 2016). A reversible hydroelectric plant (UHR) has one upper water reservoir and one lower water reservoir. The water is pumped from the lower reservoir to the upper reservoir during periods of low energy demand in the system, being released to be tilted when the energy demand rises (ZUCULIN et al, 2011). Although, quantitatively, there is no coping with UHRs, there are other energy storage technologies. In this group, it is worth noting the conventional electric batteries (approximately 700 MW of installed capacity in the world), but there is also energy storage in compressed air (CAES), thermal storage, flywheels, flow batteries, among others Technologies whose percentage share of total installed power is still very low. The prospect for the coming decades is a considerable increase in the installed capacity of energy storage. Over the next 20 years, a total of 300 GW should be added to the existing power (GUERREIRO, 2016).

this sense, power electronics plays a crucial role, since, if well used, it can exert a dual function in the distributed generation-grid interface. Since the intermittent sources generate in direct current, to be connected to the network, it is necessary to carry out a conversion to alternating current through inverters. It turns out that certain inverters have the ability to control the output voltage, not just converting continuous currents into alternating ones. With the advent of distributed generation, it is fundamental to take advantage of the control potential of this type of equipment to better control the low and medium voltage networks.

The grid voltage is another aspect affected by the expansion of distributed generation, since it has to maintain between 95% and 105% of its nominal value. The maintenance of this parameter is hampered by the intermittence of sources such as photovoltaics and by the very change of voltage brought by microgeneration nuclei. In the distribution network, the voltage in the buses, usually decreasing as it moves away from the feeder substation, has a greater fluctuation potential. At the instant that a micro generator connects to the network, for example, abrupt voltage variation in the distribution network may occur. Furthermore, conventionally, the power flow occurs only in one direction. The insertion of distributed micro generators makes it possible to reverse the flows according to the load level of the system. These issues reinforce once again the need for investments in control and protection mechanisms in distribution networks in response to the development of the mini and distributed microgeneration.

In this technical context, a factor that can contribute to reduce the technical problems caused by the expansion of micro and mini-generation is the development of intelligent networks, which refer to a new generation of electric energy networks, where technological alternatives are used in (Yan et al., 2012). In this paper, we present the results of the analysis of the electric[14] power generation and transmission system. An interesting aspect of the intelligent network is the presence of two-way communication systems, where the control centers of the electrical system control the operation of intelligent devices, and it is possible to manage the load of these devices at peak times, for example.

Table 1 highlights the main impacts on the system with respect to planning, operation and maintenance in each segment of the electric power chain, generation, transmission and distribution.

Table 1 - Impacts of Micro and Mini Generation Diffusion on the Segments of the Electric Sector

Segments	Plannig	Operation	Maintenance

[14] Another definition of smart grid is an electricity network that efficiently integrates the behaviors of all network users, consumers connected to their generators, to ensure efficient and sustainable operation of low-loss, dependable, and safe power systems (Agrell et al., 2013).

Generation	Demand forecasting and storage.	Sizing of backup power.	——
Streaming	Forecast of demand.	Voltage control.	——
Distribution	Accommodation capacity.	Capacity of lodging and islanding.	Need for investments in voltage regulators, LTC and other equipment.

Fonte: Elaboração própria

It is concluded, therefore, that the Brazilian electric sector undergoes a transformation marked by the inflow of the mini and the distributed microgeneration. It happens that the current infrastructure, as well as the operational characteristics, are not yet adapted to this imminent change. Technical issues related to voltage control, power flow inversion, loss increase, among others, should be considered in the investment decisions of the distributors, through the adaptation of the physical network and the development of intelligent networks. The potential impact of these and other aspects associated with the diffusion of the mini and distributed micro generation on the finances of the distributors will be discussed in the following section

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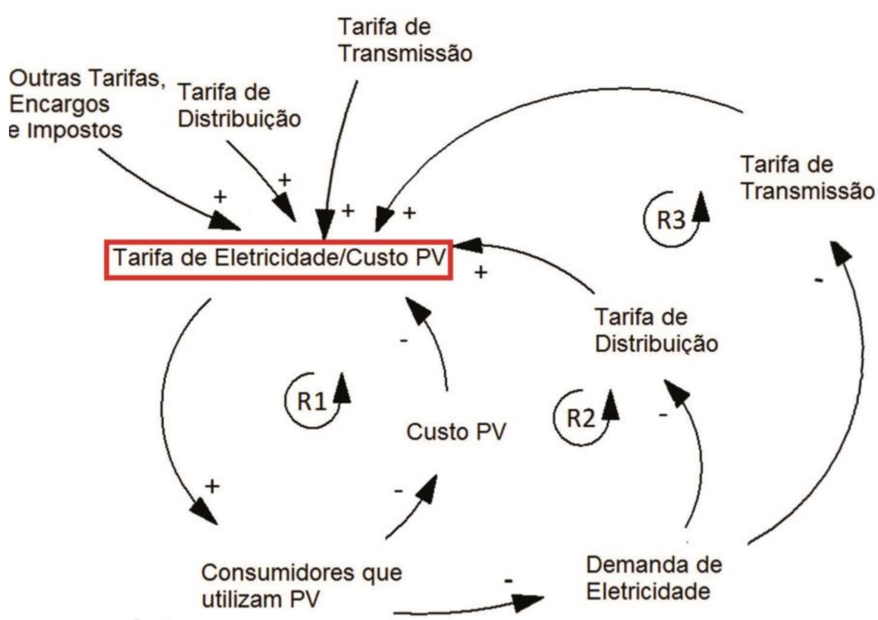
4

Economic and Financial Viability of Distributors with the Diffusion of Micro and Mini Generation

The attractiveness to the consumer of the installation of photovoltaic systems is a function of the relation between the electricity tariff (TE) and the cost of installing a photovoltaic system (CPV). Therefore, increases in electricity[15] tariffs and / or cost reductions in photovoltaic systems tend to make investment more attractive. In this context, it is observed that the increase in the number of residences equipped with photovoltaic system results in reduction of costs of the same due to economies of scale (R1) gains. As a consequence, the installation of photovoltaic systems becomes more attractive and the increase in the number of consumers using photovoltaic panels reduces the demand for electricity and therefore leads to the need to readjust the distribution and transmission tariffs respectively represented by Effects R 2 and R 3, again leading to increases in the TE / CPV ratio. This dynamic is illustrated in a simplified way through Figure 1.

Figure 1 - General model of diffusion of photovoltaic generation



Fonte: Adaptado de Dyner *et al.*(2016)

The cyclic scheme of Figure 1 is known as the "Death Spiral". The term emerged for the first time in the 1970s, in an international context of oil crisis, when the demand for electric energy was reduced and, at the same time, the capital and operating costs of the distributors rose. The term

[15] Such increases may be associated with increases in energy acquisition expenditures, network usage charges, charges or even the tax burden.

has become widely used by economists and analysts to describe the possibility of a vicious cycle of cost increases and declining demand. The initial drop in the level of electricity consumption forces distributors to pass on their costs to a smaller amount of energy consumed, making the tariff more expensive. The fact that the absolute costs have increased as a result of the crisis makes the tariff increase even more severe. This increase, in turn, may induce a further reduction of consumption. Nevertheless, the process did not unfold in the manner expected by theory, and a decade later, as pointed out by Felder and Athawale (2014), the death spiral was considered to be the result of unreliable conditions related to consumer reaction.

At the end of 2013, the term returned to gain great repercussion from the media with the publication of an article in The Wall Street Journal, where it was mentioned in a new light. This resumption of attention to this phenomenon, however, began to re-emerge, to a lesser extent, even before the article was published, due to new uncertainties related to the growing dissemination of distributed generation. The realization of the "death spiral" depends not only on the "if", but also on "how much" consumers will react to rising electricity tariffs. This is exactly the point where the proximity of a distributed generation tariff parity scenario can affect. In these terms, the possibility of migration to distributed generation has made the consumer reaction more active. It is noted that distributed generation challenges the very nature of the natural monopoly of electric power distribution concessionaires.

The dynamics mentioned above has a simplified character. For a more precise and in-depth analysis, it is necessary to add more information about the characteristics of the tariff structure, the demand, the possible diffusion of the distributed generation, and the equilibrium conditions.

In Brazil, the electricity supply tariff follows a criterion of cost remuneration in two categories:

(i) Non-manageable costs (Portion A), which contain the costs of energy purchase and those associated with transmission and sector charges; and
(ii) Manageable costs (Parcel B), which are the costs of providing the distribution service and the remuneration of physical capital investments made by the distributors.

The costs of Parcel A, paid by the distributor, are transferred in full to the tariff. Parcel B costs must be approved by ANEEL, following the principles of prudence and efficiency, considering the costs of providing the distribution service and the remuneration and depreciation of the assets linked to the provision of the distribution service. After determining the costs of Parcel B, the regulator can calculate the Revenue Required, which is the necessary revenue so that the distributor can pay all its costs and can obtain a fair return of the physical investments that made to enable the offer of services. This required revenue will be reviewed periodically, in the processes of tariff revision, that usually occurs every four years. However, new estimates and adjustments are made each year on Parcel A of the distributor based on the IGP-M distributors. This annual review also applies the so-called "X Factor", which aims to allow the appropriation of part of the gains of scale and productivity by the consumer, acting as an incentive to efficiency gains.

Another way of realizing the cost separation of the distributor is by its technical nature. The distributor's electricity supply tariff can be divided into:

(i) Energy tariff (TE), related to the payment of electricity purchase costs and sector charges; and
(ii) TUSD: tariff of the use of the distribution system (TUSD), paid by the captive and free consumers that is destined to the remuneration of the investments and services of the distribution and transmission concessionaires.

The costs that form the TE are remunerated volumetrically: each consumer pays according to their level of consumption. The demand for the subsequent period is estimated, and from this, the unit tariff per unit of consumption (whether this unit is a kWh or a MWh) is calculated to cover the costs. At the same time, part of the existing TUSD costs are remunerated by the same volumetric principle of consumption, and in the case of consumers connected in the low voltage network the entire TUSD is based on the volumetric principle. The other party is remunerated by the collection of a fixed rate based on the power contracted.

Although more details on charging based on volumetric criteria are beyond the scope of this text, it is important to understand that such criteria are subject to forecasting errors.

In this sense, charging for power assumes relevance. This relationship between charging by volumetric criteria and power tariff is essential to analyze the possibility of a spiral of death.

It should be noted that the impacts derived from the entry of consumers into the new distributed generation paradigm for distributors will be temporarily different. Therefore, it is important to examine the dynamics prospected for the short term and the one envisaged in the long term.

4.1. Short term

In the short term the migration of consumers to the distributed generation can bring losses and affect their cash flow between the periods of tariff revision. This is due to the effect of the migration, which will cause a smaller volume of consumption. As the tariff structure is formed in such a way that part of the costs is covered from the volume of consumption, and if this volume is less than expected, the rate multiplied by the consumption will generate a revenue less than that required to remunerate the distributors. That is, regulatory lag becomes a risk for distributors in case of distributed generation input. Under the current regulation, the tariff is readjusted to the new demand, but the losses incurred are not recovered. In parts, it is this short-term phenomenon that makes distributors opposed to distributed generation inflows.

One solution to the short-term problem described above is decoupling. It aims to compensate distributors over costs regardless of the volume of energy sales. That is, if the demand forecast does not materialize and, for example, is lower, the revenue losses of this period will be compensated in the following period, with an increase of the tariff. The same is true if the error is an overestimate. The most purchased revenue in this period will be used as a "subsidy" in the new tariff. This decoupling mechanism acts through so-called balancing accounts, which record these differences. In this way, there is no accumulation of losses. It can be considered that the distributor becomes, in the short term, indifferent to the input of distributed generation.

However, it is necessary to emphasize that, if on the one hand the decoupling acts to encourage the entry of distributed generation, on the other hand generates an adverse incentive. A distribution concessionaire protected by decoupling will be encouraged to raise its asset base and, on many occasions, seek to expand its costs through physical capital goods (CAPEX increase) rather than through more efficient operation (Increase of OPEX). This incentive is the Averch-Johnson[16] effect. Steve Kihm (2009) demonstrates this effect. The remuneration for the services provided by a distributor must take into account its investment cost (CAPEX) and its operating and maintenance costs (OPEX). OPEX is only covered by the required revenue. CAPEX is not only covered, but takes into account a rate of return on capital, based on its opportunity cost. The calculation of this remuneration is based on the weighted average cost of capital (WACC). Due to the information asymmetries between the regulator and the agents, the regulator has difficulty in determining exactly the true capital costs (WACC). The costs could never be underestimated, because in this way the distribution concessionaire would not enter into the business. Costs must be, either estimated accurately or overestimated, so that the concessionaire has the economic and financial incentive to stay in business.

The estimation of cost with accuracy is impractical, due to the difficulties related to information asymmetry. In this case, it is most likely that costs (WACC) will generally be overestimated. Therefore, in most cases, the distributors receive a remuneration for the capital invested above their opportunity cost. If the decoupling is used, the security of remuneration for this higher rate of return coupled with the gains of this remuneration above the opportunity cost will generate incentives for the increase of this asset base, ie incentives to increase CAPEX.

The entry of distributed generation will require new investments to ensure technical feasibility, especially in relation to the intermittency. Initially, physical investments in the network will be essential. However, after this initial phase, distribution utilities can maintain their usual practices (acting business as usual) or they can use distributed generation proactively, contributing to efficient management and making the initial problem partially a solution (THINK, 2013). That is, if distributors opt for a business as usual drive, the difficulties of subsequent entries will occur, mostly, through investments in physical capital, raising CAPEX. On the other hand, if the strategy of using distributed generation for network management is prioritized, then much of the increase in business-as-usual CAPEX costs will be replaced by an increase in OPEX, since more proactive management of generation input Will be able to delay part of the network investments. Thus, if an electric energy distributor is protected by decoupling, and has incentives to invest in capital, raising its CAPEX, the strategic decision to be adopted as the most effective is the business as usual. This is the negative effect of decoupling.

On the other hand, decoupling has an advantage related to the ease of obtaining capital at a reduced cost. The cost of capital of a distributor depends in part on the stability of profit forecasting. Investors can invest financially in fixed income or in equity. Fixed-income investments are safer, hold less risk and pay at a lower rate than equity investment. Equity investments are

[16] The Averch-Johnson effect is the tendency for regulated companies to engage in excess capital investments in order to increase the volume of their profits.

subject to risks, but usually have a higher yield. Historically, investors have always identified businesses in regulated markets as good investments from a security standpoint, since properly enforced regulation will protect the regulated firm and allow a fair return (ERA, 2013). However, the entry of distributed generation, as analyzed previously, threatens the stability and profitability of distributors in the short term, due to the accumulation of losses derived from regulatory lag, and in the long term, through the "death spiral". This instability and increased predictability of profits would raise the cost of capital, making the tariff higher. Decoupling, by ensuring regulated return, eliminates the possibility of increases arising from short-term uncertainty, and may reduce their effect on the cost of capital.

Therefore, decoupling as a short-term solution will have mixed results in relation to its influence on the tariff. If, on the one hand, there is a clear incentive to expand investments by increasing physical capital, raising CAPEX and making the operation less efficient than it could be, on the other hand, it makes it possible to obtain capital with lower costs. The effect on the tariff is not clear ex ante.

4.2. longo prazo

With regard to the long-term, one must better understand the determining conditions for the effective concretization of the "death spiral", which is a type of unstable equilibrium. This implies that when there is a first disturbance, the equilibrium will no longer be restored, since the variables will tend to follow trajectories of divergence and will no longer be equalized. Henderson (1986) demonstrates analytically what is the necessary condition for a stable equilibrium.

A presentation of the conditions makes it necessary to understand the term price elasticity of demand, defined as the ratio between the percentage variation of the quantity and the percentage variation of the price. In other words, how much, in percentage, does the quantity demanded change when there is a percentage change in price.

Henderson's condition is more easily disposed following the equation used by Costello and Hemphil (2014):

Equation 1 - Henderson condition.

$$e > \frac{P}{cm - P}$$

Wave:

e *represents the price elasticity of demand,* ***P*** *represents the price (or tariff) and* ***cm*** *represents the marginal cost*[17].

That is, when the response of consumer demand is very high, to the point of overcoming the right-side reason, an unstable equilibrium will result, resulting in the "death spiral". It is then necessary to understand the factors that affect this inequality.

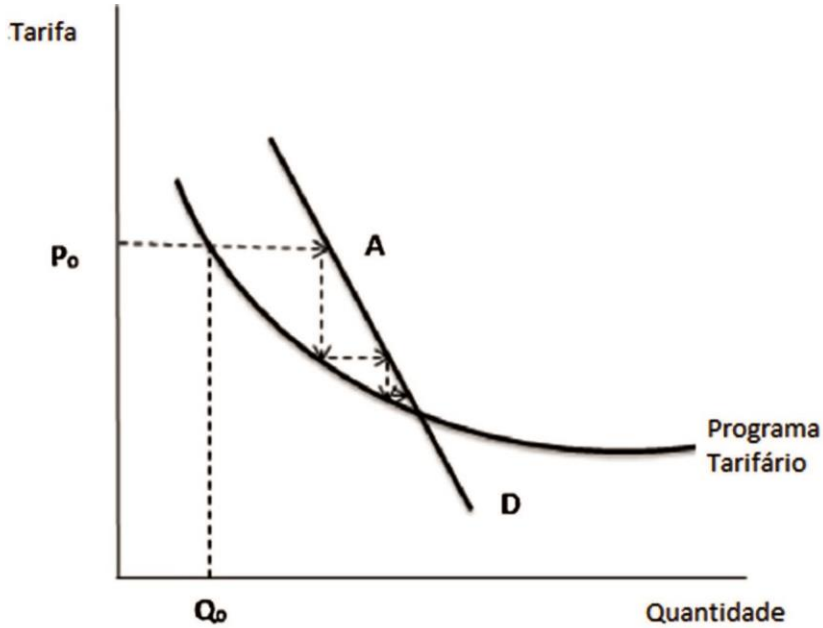
Starting with the right side of the inequality, we can notice the presence of two variables: price and marginal cost. The price is the tariff, and this is regulated by the Revenue Required and the volume of consumption. That is, there is little control over the tariff level once the tariff structure is defined. However, a tariff structure that allows the decoupling of the remuneration of fixed costs (which does not decrease with the fall in consumption) of the volume consumed, can make it less subject to sudden increases due to the fall in the volume consumed. This question will be discussed later, with the suggestion of a binomial rate.

As for the elasticity, this depends mainly on the existence of substitute goods. In the case of distributors, it refers to substitutes for power supply, where distributed generation enters, which challenges the distributor's natural monopoly role. When you create an option, the elasticity increases because consumers can migrate to it if prices become higher.

This equilibrium condition can be viewed graphically. First, however, it is necessary to introduce the concept of a tariff program. The tariff depends on two factors: Revenue Required and amount of energy consumed. For different amounts of energy consumed and a fixed Revenue Required, there will be different tariffs that satisfy the condition of attending to this. This relationship is called the tariff program. The elasticity (left side of the equation) can be seen as the slope of the demand curve. The right side of the "spiral of death" condition is the slope of the tariff program. That is, the above condition can be interpreted as a function of the slope of the demand curve and the tariff schedule. Whenever the demand curve is less inclined (supposes high elasticity) than the tariff schedule curve, there will be the possibility of disturbances, such as a first migration to the distributed generation by some captive consumers, which will determine the "spiral of death". Figure 11 illustrates the case of a stable market, with the demand curve more steep than the tariff schedule.

Graph 11 - Example of a Stable Electrical Distribution Market.

[17] O custo marginal é o custo de produzir uma unidade a mais. Neste caso, de fornecer um MW/h a mais, por exemplo.

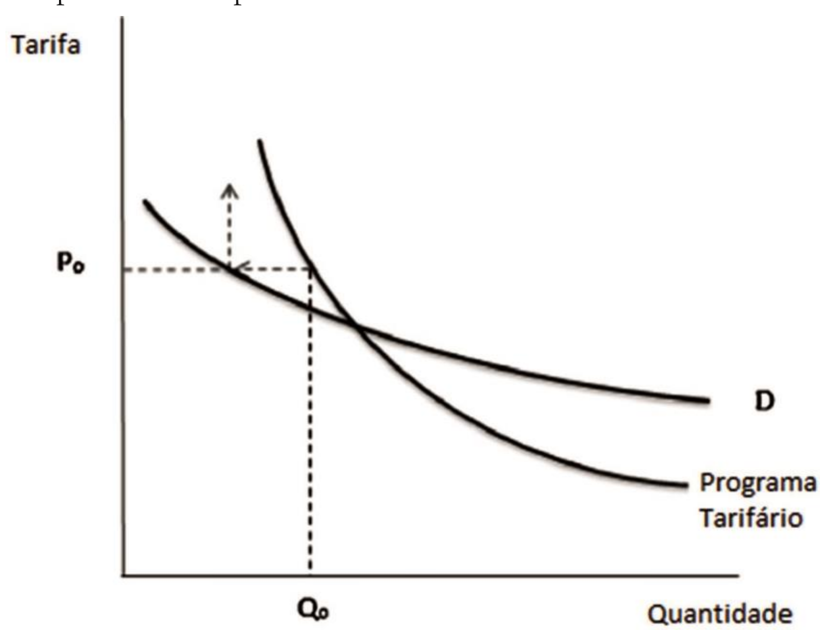


Fonte: Adaptado de Costello e Hemphil (2014)

In this graph, when the price increases, the demand curve takes off to the left and a new equilibrium is obtained. There is no endogenous feedback for this balance to be disturbed. It is as if, after an entry of consumers into the distributed generation, there was not a great stimulus for others to migrate, either because the price did not go up much or because the costs of migration did not fall much.

Graph 12 seeks to illustrate the case of an unstable market, where a price increase will shift demand in such a way that a further price increase will be necessary, which in turn will further push up demand, making any balance impossible.

Graph 12 - Example of an Unstable Electrical Distribution Market.



Fonte: Adaptado de Costello e Hemphil (2014)

Once clarified how distributed generation creates conditions for the "death spiral," it is necessary to analyze how this possibility can be answered. In other words, how to change the right side of the inequality that leads to the "death spiral".

Marginal cost is difficult to change over the short term. Its change depends on technological progress and management improvements. However, as long as there is some control over it and as long as the costs of its change do not affect the tariff, which is the other component on the right side, its reduction should be sought. A drop in marginal cost allows a higher elasticity.

The other component is the tariff, which depends on the tariff structure. One way of making this component less reactive to consumption declines, from consumer migration to distributed generation, for example, is to make fixed costs less dependent on volumetric character. A simple way to understand this is to realize that declines in consumption will result in variable cost falls, but not in fixed cost falls, which will remain the same. Thus, if the fixed costs remuneration is stable in the tariff structure, falls in consumption will result in lower tariff increases. The tariff in which there is a separation of fixed costs from variable costs of supply in the energy tariff, remunerating the former by a fixed rate and the latter by volumetric criterion is called the binomial tariff. Figueiredo (2016) emphasizes the importance of the segregation of tariff components for the remuneration of yarn and commodity electricity, since the adequacy of the tariff structure is crucial not only to provide adequate economic signals to consumers, but also as a means of guaranteeing Distributors' financial sustainability.

Andrade (2016) exemplifies the process described above by demonstrating the impact of the diffusion of micro and mini generation, under the current regulatory framework, on Light's revenue. The author argues that since 2013 the share of the A share in the electricity tariff has increased considerably, which implied a successive reduction of the share of the Distribution portion. This trend significantly compressed the regulatory EBITDA, which is the portion of the tariff that effectively remunerates the shareholder for the investments. For example, between November 2013 and November 2015, portion B went from 23% to 13% of Light's invoice, with regulatory EBITDA accounting for only 7.6% of this amount. Andrade refers to Public Hearing 026/2015 (ANEEL, 2015), where the technical note projected that in the scenario of greater diffusion of the micro and the mini generation, the maximum impact would be of 2.3% in terms of reduction of revenue of the distributors . However, the author shows that when this projected percentage is rebounded in EBITDA, the impact on the distributor's remuneration up to the Periodic Rate Review would be 30%, which would result in a strong economic imbalance.

The author also points out that the amount paid by consumers of group B (Low Voltage) as a minimum tariff is much to the payment of the cost of the network service provided by the distributor. In the case of a biphasic B3 customer, for example, in the case of a verified consumption of 10,000 kWh-month, the amount destined to the payment of the infrastructure (of the invoice of R $ 5,435) would be R $ 1,250. However, if the consumer migrates to distributed generation and has lower consumption than generation, then he will pay the minimum tariff, in the amount of R $ 54. Andrade questions, therefore, the efficiency of the signal of price issued in this situation. It argues that, at first, that difference will be paid by the distributor; Subsequently, however, will be prorated by the remaining consumers. This situation clearly illustrates the existence of a perverse subsidy, which transfers income from the lower income consumer to the higher income consumer.

The binomial fare also affects the elasticity, the left side component of Equation 1 in the condition of the death spiral. The migration to the distributed generation, with the current tariff structure, allows a reduction of the payment of the fixed costs for the consumers, since part of these depends on the volumetric criterion. In other words, consumers who migrate to distributed generation will not pay for much of the network costs. As seen by Andrade (2016), there is some degree of correlation between income and migration for distributed generation, since some captive consumers do not have the financial conditions to invest in micro- and mini-irrigation. In this way, this would be a perverse subsidy, with lower income consumers subsidizing higher income consumers. Those who must pay for these costs are the captive consumers who have not migrated to the distributed generation. This mechanism is a cross-subsidy, with consumers migrating being subsidized by consumers who remain fully dependent on the network. The binomial rate eliminates the cross subsidy. Without this subsidy, the degree of attractiveness of the distributed generation decreases, which in turn reduces the elasticity.

One of the major challenges in developing the binomial tariff is to determine a criterion of fixed cost discrimination among consumers that has a minimum degree of dependence on the distribution network. The volumetric criterion allows for very efficient discrimination of costs from consumption: Consumers who consume more (and possibly own more income) pay a higher volume of these costs than consumers who consume less (usually with a lower income). When this instrument of discrimination is lost, since consumers migrating to distributed generation no longer consume only energy supplied by the distributor, but also own energy, it must be replaced by another, which has some degree of correlation with income and The use of the network.

This criterion of discrimination is important and must be respected. If, for example, all consumers have to pay a flat rate portion exactly the same, in order to cover the fixed costs of the distributors, there is no discrimination. The resulting effect is that consumers with lower incomes, lower consumption and possibly less use of the network will have to pay a considerable part of their tariff just to pay the fixed costs, which were previously low. That is, there was a transfer of costs from consumers of higher consumption to those of children.

One suggestion to discriminate and allocate fixed costs in a fixed way among consumers is to use the power criterion. It is possible to measure the power of use of the network even with a very small consumption. And power, it is expected, has a close relationship with the level of consumption and income, though not perfect. It may not be such an appropriate tool for discriminating, but it is much better than charging a uniform tariff for all consumers.

Conclusions

It is important to highlight that the growth of micro and mini generation participation should not be analyzed as a mere diversification of the electric matrix. This interpretation tends to minimize the need for adjustments in:

(i) Operating System Paradigm;
(ii) Regulatory framework; and
(iii) Business Models

In general, it is necessary to recognize that a technological transition is taking place that will impact the electric sector in its different spheres. Not only is the continuity of micro and mini-generation diffusion and the increasing importance of demand management, but also the impacts of the increasing participation of electric vehicles in the fleet of electric vehicles, especially considering the possibility of the vehicle to Grid, corroborating drive of possible dissemination of energy storage systems in the consumption units. This technological revolution and the set of measures that will be taken to guarantee its diffusion can be defined as Distributed Energy Resources, being associated with the implementation of intelligent metering systems and the increasing automation of the electric network. It is possible to glimpse a system where consumers are prosumers and, at the same time, the electrical devices are monitored in real time within the concept of "internet of things”.

An electrical system characterized by the presence of distributed energy resources and intelligent networks should be understood as the advancement of the technological frontier. The implementation of these technologies and measures are of great importance for ensuring the supply of electricity to occur based on higher levels of quality and sustainability. In any case, since it consists of a process of energy transition, the need to consider economic, regulatory, political and social issues is also perceptible.

ANEEL's current approach to distributed generation emphasizes and stimulates the diffusion of micro and mini-generation systems technology, not yet assessing aspects associated with existing energy contracts, loss of revenues from the distributor, need for investments in new equipment Network for dealing with, for example, reverse energy flows, implementation of new procedures and tools associated with operation and maintenance, implementation of new service quality indexes, implementation of new safety criteria, expansion planning aspects and reinforcements in the network And finally new criteria for contracting energy. Thus, given the incipient state of technological diffusion of Distributed Energy Resources, the problems presented are still not clearly identified and quantified with clarity and precision, in particular the emphasis that must be placed on the creation of financial conditions for the promotion of diffusion.

Although Brazil has already advanced in some aspects related to the insertion of the micro and the mini generation, it is observed that the regulatory framework is not yet able to deal with all the changes and impacts of the diffusion of the micro and mini generation in the electrical systems. The study of international experience reveals several regulatory issues that must be studied to promote safe diffusion to maintain the technical and economic feasibility of distributors and to guarantee a fair tariff for users who do not intend to migrate to the use of micro and mini generation . Therefore, there are uncertainties about the form of performance and compensation mechanisms of distribution companies, due to the need to provide a reliable network. All this makes it essential to analyze the diffusion potential of these technologies, the examination of the systemic impacts of this process and the proposition of adjustments and regulatory innovations.

It should be noted that regulatory incentives to distributed generation act as catalysts of the aforementioned process, causing direct impacts, such as discounts on TUSD and need for distribution network adequacy, and indirect, such as reduction of consumption and revenues of distributors. The role of regulation is essential and strategic in order to avoid that the process of diffusion of the distributed generation in the matrix is given in economical and technical bases little robust, in order to guarantee the maximum social benefit made possible by Distributed Energy Resources. This balance could be achieved, for example, through the introduction of differentiated[18] tariffs and the encouragement of the use of technologies that have a greater systemic synergy with the network.

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[18] This type of tariff would allow an adequate regulatory signal, through a better separation between the payment for the electric network (wire) and the commodity (energy) (Figueiredo, 2016). Currently, Article 13 of Decree 62.724 / 1968, prevents collection through differentiated tariffs, but Aneel intends to revise this decree until 2019 (Andrade, 2016).

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