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Perspectives of PV Microgeneration in Brazil: A Proposition of Regulation Enhancement Methodology

João Lucas Fontinele Victor[1], Sandro César Silveira Jucá[1], Renata Imaculada Soares Pereira[2], Solonildo Almeida da Silva[3]

[1]Renewable Energy Department, Federal Institute of Ceará (IFCE), Brazil
E-mail: jlucasfontinele@gmail.com, sandrojuca@ifce.edu.br
[2] Electrical Engineering Department, Federal University of Ceará (UFC), Brazil
E-mail: renata@dee.ufc.br
[3] Pedagogical Department, Federal Institute of Ceará (IFCE), Brazil
E-mail: solonildo@ifce.edu.br

***Abstract*—*The solar photovoltaic (PV) generation is disseminating on multiple kinds of sites due to the energy market liberalization, the renewable energy sources subsidies policy, the decreasing of acquisition costs and the adaptability to different installation conditions. These factors allowed the growth of PV generation, especially in the distributed generation (DG) segment. Meanwhile, the development of a legal and regulatory apparatus became mandatory to assure benefits to DG-adopters, without causing damages to the utility grid, preventing technical failures and eventual excessive pricing to non-adopters. As the technology innovations impose new possibilities and the number of adopters grows exponentially, the challenges become more visible and a regulation update, urgent. In this context, this paper aims to review the current pricing model for DG in Brazil, focusing on PV microgeneration, and to propose a methodology based on the Delphi Method to enhance the most critical topics of the on-going regulation.*

Keywords*— *Solar Photovoltaic Energy, Distributed Generation, Net Energy Metering, Delphi Method.

I. INTRODUCTION

The Intergovernmental Panel on Climate Change (IPCC) reported that heat and energy generation, as well as correlated activities (processing, transmission, and storage) accounted for 34,6% of greenhouse gases (GHG) emissions in 2014 [1]. As the global temperature rises and greatly impacts on the biosphere and on the human life quality, the establishment of a worldwide agenda to promote renewable energy sources (RES) and to reduce fossil fuels consumption became a necessity to humankind survival [2]. Hence, in 2016 the RES-generation answered for approximately 62% of new power additions to the world grid, 47% of which represented the PV-generation share. The environmental benefits add up to the economic ones: more than 9.82 million created globally are linked directly or indirectly to this sector, with an annually cash flow above 200 billion American dollars (US$) along the last eight years [3].

Simultaneous to the increasing participation of RES in the energy generation share, a shift in the consumer relations occurred in several market sectors, including the energy market, predominantly dominated, especially in the case of Brazil, by a centralized structure, characterized by centralized power generation in large hydropower plants and wired to main consumer centers by long-distance transmission lines. Thus, the technological advances in electronic sciences allied to the liberalization of the energy market, which started in Brazil in the mid-90s, turned the business environment more attractive to cost reduction demands through self-generation and energy commercialization [4,5].

The intersection of both phenomena, demand for self-generation and RES promotion policies, privileged the solar PV when compared to other RES, especially among residential and small commercial sectors. The privilege of PV generation, in this case, links directly to the great distribution of solar resource; high modularity and adaptability of PV installations to buildings and urban areas; easy installation and operations with low impacts during and after its realization; reduced need of maintenance; besides the descendent costs of equipment acquisition during the past years [2,6].

In this scenario, the distributed generation (DG) emerge as any generation system connected to the utility grid, close to the consumer unit and targeting its energy demands. Beyond the environmental and economic advantages, DG based on PV microgeneration supplies short-period demand increases; enhances the global efficiency of the system by reducing distribution and transmission losses; and contributes to the stability and reliability of the electrical system by providing power reserve with lower failure risks. Nevertheless, the penetration of the DG imposes challenges of technical and economic nature, such as a higher complexity of planning, coordination and operation of the energy system; and a lower income of the utilities, which may lead to energy pricing rises [4-6].

This paper aims to review the current legal panorama in Brazil for DG based on PV microgeneration with focus on the pricing policy and to propose a methodology based on the Delphi Method to point viable solution for the critical points. Thus, Section 2 describes the evolution of the Brazilian regulation model on the main areas of interest. Section 3 describes the current situation and the critical points for PV microgeneration deployment. Section 4 introduces the main concepts of the Delphi Method and briefly reviews its utilization by other authors, while Section 5 presents the proposed methodology. At last, Section 6 concludes this paper andpoints out important remarks, relating future expectations.

II. EVOLUTION OF THE DG BASED ON PV MICRO-GENERATION REGULATION

The main regulation of Brazil on DG based on RES dates from 2012, with the approval of the Normative Resolution (REN) 482/2012 by the National Agency of Electric Energy (ANEEL). Despite REN 482/2012, the legal aspects of DG in Brazil remain diffuse and does not apply as a structured promotion policy [7]. The following discussion describes the regulation in four distinct macro-areas: administrative (includes pricing model), environmental, fiscal and technical.

2.1 Administrative regulation and pricing model

The law n° 10,439 of April 26, 2002 and the decree n° 5,163 of July 30, 2004 paved the road for RES development in Brazil. The first one created the National Program of Incentives to Alternative Sources (PROINFA) to foment the energy generation through wind power, biomass combustion and small hydro by independent producers. The second one indicates the guidelines for energy commercialization, in addition of legally defining DG as any generation plant connected directly to the distribution grid of a buyer (permission holder, concession holder or any legally authorized agent) excepting hydropower plants above 30MW and thermal power plant based on fossil fuels or cogeneration with efficiency rate lower than 75% [8,9].

Following those, REN 77/2004 describedasubsidization chronogramfor DG based on RES power plants, reducing or abolishing the distribution grid charges, while REN 167/2005 restricted the DG installed capacity to a maximum of 10% of each utility peak demand and formalized the commercialization bureaucratic process between the utility and the DG-entrepreneur [8,9].

Nevertheless, only in 2012, with the publication of the REN 482/2012, the ANEEL would set a more direct legal approach to PV microgeneration, reviewing some of the former guidelines and establishing the Net Energy Metering (NEM) as the pricing model in force [7,10-13]. The main points of REN 482/2012 and its updates are detailed in Table 1:

Table.1: Highlights of REN 482/2012 and following updates [7,10-13]

REN 482/2012	▪ Establishes NEM as the pricing model; ▪ Defines microgeneration as plants with installed capacity lower than 100kW and minigeneration, between 100 kW and 1 MW; ▪ Limits the DG to self-generation by solar PV, solar thermal, wind, biomass and small hydro; ▪ Allows the charge for grid availability; ▪ Determines the compensation period as 36 months; ▪ Abolishes any previous installed capacity cap.
REN 517/2012	▪ Allows remote self-generation; ▪ Allows energy credit transference between different consumer units inside the same utility grid and belonging to the same registered CPF (equivalent to Social Security Number in the US) or CNPJ (equivalent to EIN in the US); ▪ Restricts the DG plant installed capacity to the grid availability of the consumer unit.
REN 687/2015	▪ Reduces microgeneration installed capacity limitto 75kW and expands the minigeneration to 5MW, excepting small hydro; ▪ Increases compensation period up to 60 months; ▪ Establishes new business models: condominiums, consortiums and cooperatives.
Circular Letter 010/2017	▪ Emphasizes the illegality of the division of a consumer unit, aiming to pass the DG plant as mini- or microgeneration; ▪ Emphasizes the illegality of charging in basis of generation (R$/kWh).

2.2 Environmental regulation

The Resolution n° 001 of 1986 of the National Board on Environment and Renewable Resources (CONAMA) dismisses the presentation of an Environmental Impact Assessment (EIA) for any power plant with installed capacity lower than 10MW. There is a lack of specific federal regulation for mini- and microgeneration regardless of the energy source [14]. Thereby, the state environmental agencies answer for most of the legal aspects regarding DG. In general, plants with an installed capacity lower than 1 MW are dismissed of licensing, and those between 1 MW and 5 MW have a simplified legal procedure.

2.3 Fiscal regulation

The fiscal regulation encompasses subsidies in two different areas: equipment purchasing and energy generation billing. The Agreement 101/1997 of the National Finance Policy Council (CONFAZ)represents the first one, exonerating all state-level commercialization taxes (ICMS) for PV generators and wind turbines. Furthermore, energy generation billing subsidies involve tax-release from both levels of government, federal and state. The federal law n° 13.169 of 2015 modifies the energy bill tax calculation, applying the charges only on net consumption, rather than total energy consumption. Following that, the Agreement 16/2005 of the CONFAZ also applied the same calculation method for ICMS. However, 4 out of 27 states are non-signatory of this agreement [7,12], as explicit in Table 2. It is also important to highlight the fact that both federal and state taxes represent an average of a third of the energy bill final amount.

Table 2: Signatory and Non-Signatory Brazilian states of CONFAZ Agreement 16/2005

Signatory States	Non-SignatoryStates
Acre,Amapá, Alagoas, Bahia, Ceará, Distrito Federal, Goiás, Maranhão, Mato Grosso, Mato Grosso do Sul, Minas Gerais, Pará, Paraíba, Pernambuco, Piauí, Rio de Janeiro, Rio Grande do Norte, Rio Grande do Sul, Rondônia, Roraima, São Paulo, Sergipe, Tocantins.	Amazonas, Espírito Santo, Paraná, Santa Catarina.

2.4 Technical regulation

The Manual n° 3 of the Procedure of Electric Energy Distribution in the National Grid (PRODIST), published by the ANEEL, lists the minimum criteria for access, project, operation, maintenance and security of any electrical installation connected to the grid [15]. Moreover, each utility shall elaborate their own technical procedures and standards based on their interpretation of the REN 482/2012 and its following updates. It is also a part of the utility the examination, authorization, and inspection of all installation connected to the grid.

Due to the lack of national standards for micro- and mini-generation regardless of the source, the IEEE 1547, Standard for Interconnecting Distributed Resources with Electric Power Systems, must be observed. In terms of PV generators and installations, the Brazilian Association of Technical Standards (ABNT) dictates the test procedures for anti-islanding (NBR IEC 62116); the minimum equipment technical parameters for grid connection (NBR 16149); the assessment tests to evaluate the equipment technical parameters (NBR 16150); the commissioning, inspection and evaluation procedures (NBR 16274); and the PV electrical installation minimum requests (NBR 16690), the last one still under discussion.

III. CURRENT SCENARIO AND CRITICAL POINTS

The approval of the REN 482/2012 leveraged the number of installations of DG based on RES plants. Though some of them already existed previously to the establishment of the current regulation, being added to the initial statistics, the higher share of the installed capacity represents new additions to the grid. During the last six and half years, the growth of installed capacity of DG based on RES presented an exponential curve, as showed by Fig. 1, reaching 441.5 MW till August of 2018, according to the Registration System of Distributed Generation (SISGD) maintained by ANEEL and updated by the utilities.PV mini- and microgeneration plants, represent over than three-quarters of the total capacity, adding up to the grid approximately 348.9 MW (Table 3) [16].

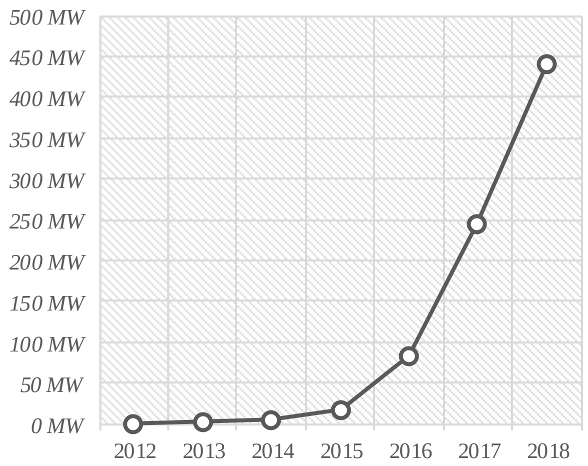

Fig. 1: DG mini- and microgeneration installed capacity growthafter REN-482 [16]

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Table.3: Total DG vs. PV mini- and microgeneration installed capacityfrom 2012 to August-2018 [16]

Year	Total DG	PV Generation
2012	0.4 MW	0.4 MW
2013	1.8 MW	1.8 MW
2014	5.2 MW	4.2 MW
2015	16.9 MW	13.8 MW
2016	83.0 MW	62.2 MW
2017	244.3 MW	183.1 MW
2018	441.5 MW	348.9 MW

In reason of the increasing installed capacity, the penetration of DG and PV microgeneration started to induce some questions or criticism by different stakeholders. Zinaman*et al* [17] comments that one of the main issues in NEM pricing models is the rate of energy exportation to the grid, leading to overcompensation and cost shifting. Eid*et al* [18] estimates the utility income losses due to PV microgeneration, concluding that the combination of volumetric energy billing and NEM leads to loss of revenue for the distribution company, especially for those units with little or no coincidence between generation and consumption peaks. Bird*et al* [19], however, affirms that for lower penetration levels, the effects on the utilities finances are neglectable and cost shifting improbable. This affirmation correlates to the Technical Note 56/2017 issued by ANEEL [20], which predictedfor the period of 2017-2024 anaveraged accumulated impact of 1.9%on energy prices caused by PV microgeneration, with most of the utilities having a predicted rate variation between 0.5 and 1.5% (Fig. 2). However, the quantification of the ideal penetration level is still unclear and concerns about changes in the future scenario of energy prices remain.

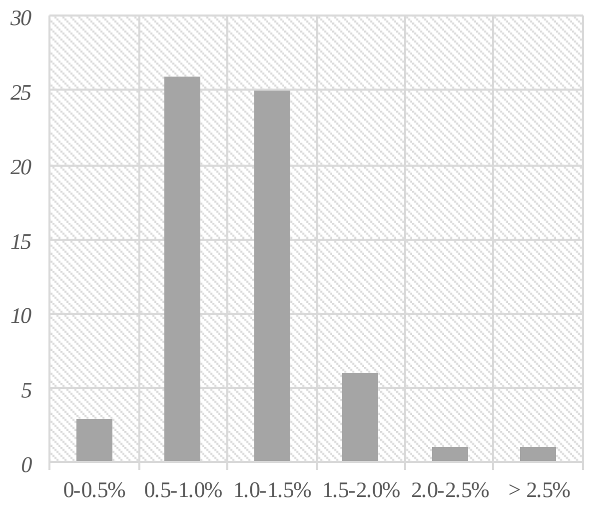

Fig. 2: Distribution of Brazilian utilities according to the impact of PV microgeneration on energy prices [20]

Section 2.1 elucidates the evolution of REN 482/2012, commenting on the existence of five business models for PV microgeneration, which present a considerable difference on the level of grid usage between them. Self-generation has the lowest usage level, while remote self-generation, consortium and cooperative may export the entire energy, generating virtual energy credit and transferring them to other consumer units. These asymmetries turn questionable the applicability of the same energy exportation rate regardless of the business model, without accounting the costs incurred to the distribution network and the impacts on its quality and functionality [17,18].

Though the expansion of the business model may lead to a further expansion of installed capacity, there are still fewer facilities framed under condominium, consortium and cooperative generation models. Partly due to the non-applicability of the Agreement 16/2015 tax exemptions to those business models and partly due to the lack of clarification about the regulation and the bureaucratic complexity [7,12].The bureaucratic complexity is also verifiable by the utility approval of the electrical project. Norms, technical requirements, and documental requests change from one distribution company to another, as well as the charges applied during the billing process, producing a range of localized impacts on the viability of the PV microgeneration installations.

Apart from that, both mini and microgeneration rely on high initial investments with great dependency on credit programs with attractive interest rates. As observed by Ramalho*et al* [7], the absence of a nation-wide program of credit financing for a private person to promote PV microgeneration along with the prohibition of energy credit selling to the distribution company diminishes the accessibility range for people of lower income and the development of new business models.

Besides those issues related to pricing, bureaucracy, and financing, the use of a bidirectional meter imposes a technical planning challenge. As the energy exported to the distribution network fluctuates in reason of the intermittency of the RES and the load curve of the consumer unit, the total amount of energy generated in the grid without subtracting consumption is unknown by the planning authorities [18]. The estimation of the generation may incur an increase in the residual error and lead to misjudgments, false premises and wrongly based decisions. As policy planning relies strongly on the reliability of the collected data, any additional variability shall be avoided.

IV. DELPHI METHOD: CONCEPT AND APPLICABILITY

Conceptualized as a method to structure a group communication process in a manner to guarantee the effectiveness of dealing with complex problems, the Delphi emerges out of the Specialists Methods as a tool to evaluate complex and interdisciplinary questions. The model delivers its final responsesover a proposed issuethrough the consensus of a group of individuals with a high level of knowledge on a specific matter.Delphi application is suitable for situations with scarcityor imprecise historical data; with extrinsic factors predominating the intrinsic ones; or else, with substantial interdisciplinary.Moreover, the Internet dissemination allows the participation of experts from different locationsin a larger number [21,22].

According to the goals of the group and the typification of the problem, there are two distinct Delphi Methods: Predictive and Political. The first one seeks to design future scenarios, assisting a decision-making process; while the second one functions as an analysis of political alternatives, exploring each angle of the situation to assess the consequences of any particular option.

A brief literature review of the application of the Delphi Method shows a diversity of studies on the Predictive area, targeting mainly the forecast of energy sources and technological potentials to assist policymaker's decisions. In this sense, Czaplicka-Kolarz*et al* [23] developed a foresight evaluation of technological advances and key sectors in the energy sector to coordinate public investments in Poland. Celiktas*et al* [24] presented a prognosis for the participation and benefits of renewable energy in Turkey by applying an online survey. Varho*et al* [25] used the method to list opportunities and challenges for DG in Finland, assessing different future scenarios and analyzing public responses and involvement to the theme.

Regarding the Political Delphi Method, the focus relies mostly on policy assessment. Carrera*et al* [26] set social indicators and, through a survey applied among experts in France, Germany, and Switzerland, rated energy technology according to its contributionto social development. Hsueh [27] took a local approach, evaluating the effectiveness of a community environmental policy involving afforestation and PV generation. The studies of Galo*et al*[28] elaborated a questionnaire to indicate the lowest cost policies for the deployment of smart grids.

In reason of the nature and purposes of this paper, the construction of the proposed methodology took basis from the Political Delphi, since this method is more adequate to the achievement of the goals mentioned on Section 1.

V. PROPOSED METHODOLOGY

The result obtainment by a participative process may only achieve consensus through an active mediation without discouraging the discussion. The active mediation shall be prepared on the discussed matter, assuring its enrichment and conducting it by pre-established, well-based and clear methodology.

As briefly pointed out in Section 3, some issues arise from the recent deployment of DG and PV microgeneration. Targeting those issues and preventing future necessities encompasses and strengthens the legal framework, creating an environment of thriving business possibilities for all stakeholders.

The following methodology based itself on the Delphi Method presented in Section 4. The main steps are schematized in Fig. 3 and detailed in the subsequent subheadings.

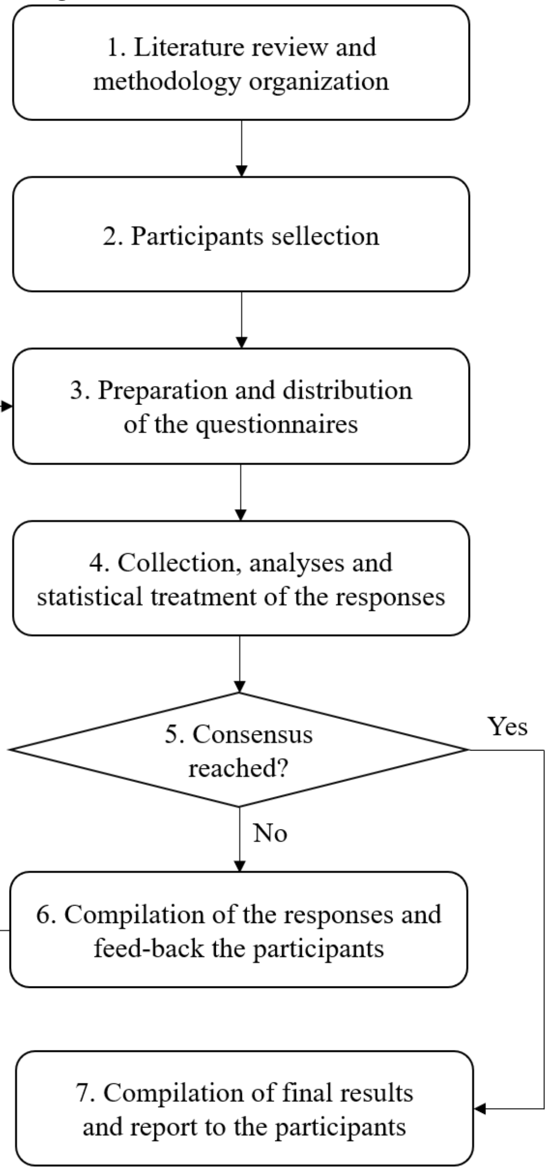

Fig. 3: Schematically representation of the regulation enhancement methodology based on Delphi Model

5.1 Literature review and methodology organization

During this step, all relevant data, report, paper or work on the future discussed matter shall be gathered and analyzed. It is also recommendable some previous surveys with key stakeholders and civil society to collect a more subjective type of information as opinions, believes and feelings toward the approached issues.

5.2 Participants selection

The invitation of experts to participate in the discussion group shall be accompanied by a clear explanation of the methodology and the importance of maintaining the level of participation through the entire process. The expert choice shall cover different activity areas of the civil society to provide a wider view on the matter and enrich the discussion. It is important not to attain to location and time issues, using a virtual tool as online forms and e-mails to ease the application of the method and minimize its time-consuming feature.

5.3 Preparation and distribution of the questionnaire

The questionnaire shall contain a previous briefing on the current scenario, presenting the main gathered data in a didactical approach without forcing any prejudice from the organization group over the discussion group.

The questions shall be clear and quantifiable; it is suggested the use of an agreement scale from 1 to 4 for the answers, avoiding a central number representing a neutral opinion over the question issue. It is also important to create groups of questions to assess each issue, presenting different approaches to the problem to force the participant over a self-contradiction situation.

Following each question, there shall be a justification request, where the participants shall use their knowledge and expertise to base an argument justifying the agreement choice.

The preparation of the questionnaire is key to the success of the methodology. Thus, it is important to maintain it as clear and concise as possible, without lacking any important point.

During the application of the questionnaire it is also recommended to avoid contact among the participants, the discussion must take part without any social-economic bias to avoid the influence of a participant over the other.

5.4 Collection, analyses and statistical treatment of the responses

The collection of the responses is followed by its analysis. The configuration of the questionnaire in an agreement scale facilitates the application of a statistical treatment, evaluating the difference level among the answers.

Following the treatment, a report shall be made to feedback the participants. The main points presented in the answers justifications must be exposed to induce a reflection on the group over different points of view, reassessing their previous answers.

5.5 Consensus reaching and final results

After a statistical treatment, the measurement of the consensus level is taken through the distance between the third and first quartile to the median. Thus, the establishment of a consensus threshold is necessary. If the quartiles-median distance is greater than the consensus threshold, the feedback report will be accompanied by a second-round questionnaire, similar to the first one, leading the participants to reevaluate their first answers in face of the answers of the group. This loop happens till the quartile-median distance is lower than the consensus threshold, indicating that the group achieved an acceptable level of agreement.

In the case of DG and PV microgeneration, the problem approach shall consider the pricing model review, the impacts of different business models over the grid, the fiscal and bureaucratic complexity and the technical issues, besides preparing the regulation for the entrance of storage systems, electric vehicles and other innovations that reached a commercial scale. A consensus over such wide matter may not be easily reached, but during the application of the subsequent rounds, the questionnaire may be adapted to focus on the gains of each participant, catalyzing the establishment of a common agreement.

VI. CONCLUSION

The deployment of DG plants, notably PV micro generation, is a worldwide trend, urging governments and policymakers to formulate proper regulation to face technical and economic issues, allying the DG and PV microgeneration main benefits with the social welfare and the quality and efficiency of the electrical system.

The approval of REN 482/2012 and subsequent establishment of NEM as pricing model favored PV microgeneration in Brazil. Nevertheless, the increasing dissemination rate and the technological innovations demand continuously regulation update.

Due to the interdisciplinarity nature of the main critical points about DG deployment and the lack of empirical data suitable for the social-economic frame of Brazil, this paper suggests the application of a methodology based on the Delphi Method to analyze and propose alternatives for DG and PV microgeneration obstacles through a consensus process among experts on this matter.

The methodology proposed in this paper aimed to serve as a participative tool to assist the enhancement of the DG and PV Microgeneration policy in Brazil and to promote tangible and balanced solutions with lower global impacts over the key stakeholders.

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