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Technical-economic analysis for the integration of PV systems in Brazil considering policy and regulatory issues

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ABSTRACT

The increasing integration of distributed renewable energy sources, such as photovoltaic (PV) systems, requires adequate regulatory schemes in order to reach economic sustainability. Incentives such as Feed-in Tariffs and Net Metering are seen as key policies to achieve this objective. While the Feed-in Tariff scheme has been widely applied in the past, it has now become less justified mainly due to the sharp decline of the PV system costs. Consequently, the Net Metering scheme is being adopted in several countries, such as Brazil, where it has is in force since 2012. In this context, this paper aims to estimate the minimum monthly residential demand for prosumers located in the different distribution concession areas in the interconnected Brazilian system that ensures the economic viability of the installation of PV systems. In addition, the potential penetration of PV-based distributed generation (DG) in residential buildings is also estimated. This study was conducted for the entire Brazilian interconnected system and it demonstrates that the integration of distributed PV systems is technical-economic feasible in several regions of the country reinforcing the role of the distributed solar energy in the diversification of Brazilian electricity matrix.

1. Introduction

1.1. Motivation

The current scenario of electricity in Brazil reached alarming levels due to its growing cost and the permanent risk of having Energy Not Supplied (ENS). Among the reasons that are contributing to this crisis the following ones can be mentioned:

- low tariffs determined during a long period by the National Regulatory Agency for Electricity (ANEEL) led the distribution companies (DisCo) to operate in financial deficit, resulting in many of them being rescued by the national treasury;
- the constant delays in the implementation of new power generation and transmission line projects;
- a high number of energy auctions, resulting in low price of energy, which prevented achieving the return rates required by the market;
- the hydric shortage had a major impact on the security of supply since the hydropower account for about 70% of Brazil's energy mix.

Therefore, the mentioned alarming scenario and the strong hydraulic dependence of the Brazilian energy mix in combination with the increasing electricity demand and the constant concern with the preservation of the environment are driving the Brazilian scientific community to look forward to exploring other renewable energy sources, such as solar. On this regard, Brazil has a large solar energy potential due to an advantageous geographical location, with most of its area in inter-tropical regions and a global incident solar radiation between 1900 and 2150 kWh/m^2 throughout the year (SolarGIS, 2017). These values are larger than in most European Union countries, such as Germany, France and Spain, where solar energy projects (some of which strongly relying on government incentives) are widely disseminated (Miranda et al., 2015).

The exploitation of energy generation from renewable sources has been increasing in several countries, in most cases induced by regulatory incentives for small distributed generation (DG) such as Feed-in Tariffs and Net Metering schemes (del Río and Mir-Artigues, 2012; Jacobsson and Lauber, 2006). These incentives are justified by the potential benefits that DGs can provide to the electrical system, namely

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the postponement of investments in the expansion of generation, transmission and distribution systems, the reduction of the environmental impacts, the reduction of the electricity demand levels, the reduction of active power losses, and the diversification of energy sources (Maciel et al., 2012). The Net Metering scheme, which is in force in Brazil since 2012, was the first strategy presented by the National Electricity Agency (ANEEL) to reduce barriers for the integration of small-scale distributed power plants based on renewable energies, such as PV systems.

1.2. Literature review

Several studies have been conducted concerning the economic viability of PV DG in Brazil based on the Net Metering regulation. In this scope, reference (Pereira et al., 2012) describes the current status in 2012 and the potential for the renewables in Brazil. Several scenarios for PV technology deployment in Brazil in the year 2030 are studied in (Jannuzzi and de Melo, 2013) considering policy mechanisms aiming at promoting the development of PV generation connected to distribution networks. Besides, an evaluation of the market penetration potential in each case using a logit-function approach was done and the results show that PV systems have good opportunities for Brazil to diversify its energy matrix while increasing the potential economic and environmental benefits. In (Lacchini and Dos Santos, 2013), the authors analyze the evolution of the integration of PV systems by comparing their total costs with coal-fired generation, furthermore, some government incentives are proposed to narrow the existing financial gap between these two technologies.

In (Dávi et al., 2016; Holdermann et al., 2014; Lacchini and Rüther, 2015) it is described an economic viability analysis of a PV system for the residential and commercial sectors after the introduction of the net metering regulation. In this study the current electricity tariffs are used as well as some fees and taxes, however the cost of electricity availability is not considered. The research reported in (Rodrigues et al., 2016) presents an economic analysis for PV systems all over the world, by comparing the policies adopted in Australia, Brazil, China, Germany, India, Iran, Italy, Japan, Portugal, South Africa, Spain, the UK and the USA in order to assess which of these countries have the most attractive policies to induce investments in PV systems. The work in (Pinto et al., 2016) uses the Brazilian solar irradiations levels in order to calculate how many PV panels are necessary to supply the average electricity demand of social housing programs and the results confirm that PV panels are an important alternative for the Brazilian energy crisis.

Finally, (de Faria et al., 2017) highlights the challenges and prospects for the PV systems on Brazilian DG describing some incentives implemented to date in order to develop the solar electricity generation. These authors were motivated by the increase participation of alternative renewable sources as wind and small hydro (while solar energy utilization is underutilized) in the electricity market, induced by mechanisms designed to stimulate its implementation as the Net Metering regulation by the normative resolution 482.

On the other hand, references (Camilo et al., 2017; Vale et al., 2017) report case studies for the PV system integration in Brazilian households considering financial and technical effects in the low voltage systems. The results prove that further regulating and market efforts are required to expand the solar generation by residential consumers.

1.3. Contribution and structure

In this study, the minimum monthly residential demand to ensure the economic viability for PV systems – the *threshold demand* – is computed for prosumers located in all distribution concession areas in Brazil. Furthermore, the potential penetration of PV systems for residential consumer is also estimated for each Brazilian region. The methodology that was adopted in this work is unprecedented in the literature in the sense that it takes into account not only the Net Metering regulation but also the Agreement 16 and the Normative Resolution 414 introduced by the Brazilian government to promote DG and specifying the general conditions of electric power supply, respectively. While these agreements and regulations are widely used by the electric industry, they were never considered in this type of study.

Regarding the structure of the paper, Section 2 presents the main strategies adopted by the government to encourage the penetration of DGs, Section 3 describes the methodology used in this study, Section 4 reports the main results and, finally, Section 5 includes the comments and conclusions that can be drawn from this work.

2. Government legislation on the Brazilian DG

2.1. The normative resolution 482 (RN482)

In April 2012, ANEEL introduced the Net Metering mechanism through the RN482 in order to reduce barriers to the connection of small renewable-based power plants to distribution networks. Net Metering is an incentive mechanism for DGs, in which an elective consumer, properly connected to a distribution network, can inject to this network the surplus energy for later use. This mechanism allows two-way energy traffic between DG and the distribution network and consequently the network can be seen as playing the role of storing energy.

However, in April 2015, i.e. three years after this normative resolution was passed, there were only 478 PV systems installed in Brazil, which led to an update of this regulation in November 2015 (ANEEL, 2015), namely addressing the limits of the installed capacity and the compensation schemes. Currently, the normative defines micro DG as an electricity generation plant with installed capacity less than or equal to 75 kW and mini DG as a unit with installed power larger than 75 kW and less than or equal to 5 MW (3 MW for hydraulic sources). In addition, the RN482 sets a compensation scheme by granting a credit to the consumers that can be used by up to 60 months if the amount of energy injected in the network is larger than the local consumption. This compensation scheme corresponds to a major change introduced by the RN482 regarding PV systems because it means that any economic analysis should take into account the monthly energy balance over the horizon plan.

2.2. The agreement 16

There are several taxes that are applied to the electric energy produced by DGs. Among those, the Goods and Services Tax (ICMS) is the most expressive one. This tax is independently established by each of the 27 Federal Units of Brazil (26 States plus the Federal District). The rates vary from 0% to 30% and there are two different ways to apply it to the electricity bill. In the first case, the base for the calculation of the ICMS is the electricity supplied by the network to the consumer whereas, in the second case, the tax is applied to the electricity balance, i.e., the difference between the electricity injected and the electricity supplied by the network.

In April 2015, the National Finance Policy Council (CONFAZ) published the Agreement 16 that authorized some states to apply the ICMS on the electricity balance (CONFAZ, 2015). In August 2017 twenty-one Federal Units have signed the agreement, namely, Pará, Acre, Alagoas, Bahia, Ceará, Goiás, Maranhão, Mato Grosso, Minas Gerais, Paraíba, Pernambuco, Piauí, Rio de Janeiro, Rio Grande do Norte, Rio Grande do Sul, Rondônia, Roraima, São Paulo, Sergipe, Tocantins, and the Federal District of Brasília. The Federal Units that did not sign this agreement are: Amazonas, Amapá, Espirito Santo, Mato Grosso do Sul, Paraná and Santa Catarina.

Government subsidies and strategies are extremely important to boost the penetration of PV systems in the distribution network (Silveira et al., 2013), which means that it is clear that an adequate incentive structure for PV systems will very much favor its penetration