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Platform for Distributed Generation Connection Assessment in Brazilian Electrical Grids

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Abstract*— *This paper presents the studies and specifications of the development of a computational platform for distributed generation connection evaluation that uses the concept of Hosting Capacity and automated individual analysis of the connection as well as a protocol to utilize this platform. The risks and problems linked to the unbridled and without criteria connection of distributed generation to the network and its connection processes are addressed. Finally, a case study applied to a real network is presented, evidencing the mitigation of potential power quality problems brought by the insertion of distributed generation and other benefits achieved with the use of the solution developed and applied.

I. INTRODUCTION

Distributed generation (DG) is the term given to the electricity generated at or near the place of consumption, and commonly uses renewable energy sources such as solar, wind, hydro, among others. Since 2012, the Brazilian consumer can generate its own electricity from renewable sources or qualified cogeneration and even provide the surplus to the distribution network of its locality in exchange for energy credits [1].

The stimuli to distributed generation are justified by the potential benefits that such a modality can provide to the electrical system. These benefits include the postponement of investments in the expansion of transmission and distribution systems, the low environmental impact, the reduction in the thermal load of equipment in the electrical grid, the minimization of power losses, and the diversification of the energy matrix [2].

Other benefits offered by DG, such as the decrease in the acquisition and implementational costs, as well as the constant incentive given by governments, brought a significant increase in the number of distributed generations connected to the Brazilian electrical grid. However, even with the numerous benefits that distributed generation offers, the unbridled connection without well-defined criteria and the carelessness with which access opinions are eventually treated can bring risks and power quality problems. One possible solution to this problem is the use of computational DG connection tools, capable of providing a fast and efficient treatment of data regarding to the connection. The presentation and characterization of a computational DG connection tools developed by the authors is the main theme of this article, as well as a demonstration of its potential in an execution applied to a real network.

In the recent period, several studies were conducted on the impact of DG on the electricity grid. These studies produced reports, articles, and even computational tools that address some aspects of the analysis process. A brief review of the main concept of the theme in the literature, Hosting Capacity, will be covered in section II.

In most cases there was no validation of the models through experiences in real situations, involving the measurement of impacts considering a sized installation of a distributed mini generation (generation greater than 75 kW but less than 5 MW). This work has advanced in this sense, incorporating new elements in the analysis through the measurements of a real installation and providing a faster evaluation of the connection. Thus, an original product was obtained that includes information for analysis not yet used in the products on the market.

In this context, this document presents the studies and results regarding the use of a platform for distributed generation connection evaluation that uses the concept of Hosting Capacity [3] and also the automated individual analysis of the connection. The text is divided into six main sections. Section I addressed the current scenario of DGs in Brazil, the problems linked to the unbridled and described connection of DGs to the network are addressed in section II, as well as their connection process in section III. The solution offered to address this problem, including specifications and assumptions adopted in the computational tool developed is presented in Section IV and, finally, a case study example is given in section V while section VI brings the conclusions of this work.

II. IMPACT OF DISTRIBUTED GENERATION ON POWER QUALITY

According to [4], the power quality criteria of the product are determined by ANEEL so that the supply of electricity is appropriate to all consumers and participants of the Brazilian electrical system. Therefore, these criteria should be met after connecting the DGs [5]. For the study of the impact that these generations have on the distribution network, it is important to look at the criteria that can be affected by it [6] and the concept of Hosting Capacity.

a. From the Criteria

- Undervoltage: It consists of reducing the value of the voltage magnitude over a short period, which should be restored to acceptable levels, defined according to [4]. The DGs are related to undervoltage due to the intermittence that characterizes this type of generation, which causes a drop in the voltage supply, thus causing undervoltage.
- Overvoltage: Criteria very similar to that described above, with the difference that here the voltage reaches levels higher than those established. When the internal consumption of the DG-powered facility is lower than the energy generated, the power is exported to the grid, which causes the voltage to increase at points near the DG connection point.
- Voltage Variation: This item discusses the voltage variation in network buses that occur over a certain time interval. Related to the two previous items, the occurrence of undervoltage and overvoltage linked to the connection of DGs to the network, which may damage equipment connected to the network, which was not made to work under such conditions.
- Regulator Voltage Variation: It can be seen as a specific instance of the previous item and refers to the consequences that voltage variation can cause on voltage regulators. These are inserted to improve the voltage profile of the grid, however, in the occurrence of overvoltage or undervoltage events, this adjustment needs to be redone, and in this period until its reconfiguration, the network voltage situation is aggravated. In addition, because they are mechanical equipment, it is not desired that its reconfiguration occurs too often, so its joint operation with distributed generation units can damage the equipment, reducing its service life.
- Equipment thermal loading: It is a parameter that indicates the amount of power that network equipment supports. With the insertion of the DGs, equipment that had initially been designed to support a maximum power or current may have to work with higher values. Thus resulting in a thermal overload that damages the equipment, reducing its service life.
- Reverse Power Flow: It is the situation in which the power flow ceases to be from the substation to the loads and is reversed. The problem of this situation is that the distribution networks were not designed for this power flow inversion so that the equipment and other structures installed in the network can be damaged in the occurrence of this phenomenon. This situation occurs predominantly when there is a high volume of DG generation and low consumption of the facilities around it.

Other criteria such as voltage imbalance, sympathetic trip, and loss of flexibility, although of great importance, were not addressed in this study, because nowadays there are no criteria commonly analyzed by Brazilian distribution utilities in requests for distributed generation connection

b. Hosting Capacity

A widely used term when it comes to the connection of DGs is the Hosting Capacity of an electrical system, which is defined as the amount of distributed generation that can be connected to it, before changes or improvements to the network are necessary to be able to operate while meeting the required quality limits. [7].

There are three classes of methodologies currently used to determine Hosting Capacity: analytical, stochastic, and simplified [8].

Analytical methods consist of systematic procedures that study the generation effect distributed on all buses of a feeder and determine the Hosting Capacity of each system bus individually. These methods, while very accurate, require a lot of processing time and are always complex due to the level of detail adopted.

On the other hand, stochastic methods, estimate multiple generation scenarios and simulate the many uncertainties related to the integration of DG, such as location and power supply. The complexity and processing time of these methods depends on the type of network being studied, as well as the accuracy desired by the planner – expressed by the number of simulated scenarios.

Finally, the simplified method establishes correlations between the results of more detailed studies and proposes a simplified analysis of accommodation capacity. In this way, the processing time is reduced, as well as its accuracy, especially for more complex systems. Given these considerations, regarding the reality of distribution utilities, the chosen method to be addressed in this work was the simplified method.

It is important to note that Hosting Capacity is not a static value as network improvements are made, the value tends to increase. It is also known that the value of Hosting Capacity will depend basically on the power of the generation, the location of the feeder, and the previous characteristics of the feeder, such as other distributed generations, topology, presence of regulators, number of consumers, etc. [7].

III. NETWORK CONNECTION PROCESS

According to [9], the process of connecting distributed generation to the Brazilian network takes place in four steps: access query, access information, access request, and access opinion, which will be detailed below.

Initially, the accessor must make the access query, making sure the criteria and procedures to be met. After this step, it is mandatory to prepare the access information according to the procedures described in [1].

After these initial stages, the access request stage starts, which is characterized by the request formulated by the accessor that, once delivered to the accessed, implies the priority of attendance, according to the chronological order of protocol.

Finally, the last step is to access opinion, which is the mandatory formal document presented by the accessed, in which the conditions of access are informed, comprising the connection and use, and the technical requirements that allow the connection of the accessor's facilities with the respective deadlines.

This document presents the characteristics of the delivery point, accompanied by estimates of the respective costs, conclusions and justifications; the characteristics of the distribution system accessed, including technical requirements, rated connection voltage, and performance standards; budget of the work, containing the memory of calculating the budgeted costs, the responsibility of the distributor and the financial participation of the consumer; the list of the works of responsibility of the access, with corresponding implementation schedule; general information related to the location of the connection, such as type of land, passageway, mechanical characteristics of the facilities, protection systems, control and telecommunications available; the mini generation Operating Agreement model [3]; the responsibilities of the accessor; and any information about equipment or loads that may cause disturbance or damage to the distribution system accessed or in the premises of other accessors.

After the execution of the entire procedure, in the technical evaluation of access, the distribution utility must observe the criterion of minimum overall cost [4] of service. According to this criterion, among the alternatives considered for enabling access, the technically equivalent alternative of the lower overall cost of investments should be chosen, observing the same time horizon for all the evaluated alternatives, considering the connection facilities of responsibility of the accessor; installations resulting from reinforcements and expansions in the electrical system and the costs arising from electrical losses in the electrical system.

After following a series of steps, the accessor will send his proposal to connect the DG to the accessed for the analysis of the feasibility of the process. Considerations such as preventing accommodation from causing power quality problems to the network and adopting the minimum overall cost criterion will be analyzed internally by the access.

Considering that the connection of DGs may cause necessary improvements on the network, the analysis made by the utility becomes an increasingly difficult process due to the complexity of the analysis and the number of access requests.

Thus, a tool capable of assessing the impact of the connection in an efficient, fast and automated way is fundamental to both the implementation of The DG connections and the maintenance of the power quality provided by distributors.

IV. SOLUTION

Given the presented, it is proposed as a solution a computational tool elaborated in C++ language and integrated to the commercial platform of electrical networks simulation, SINAPgrid.

The idea behind the tool is that it must be able to automate the process of issuing an opinion, to speed up and be more assertive in the process of analysis of the possible insertion of DG in the network, guaranteeing that its connection does not cause losses regarding the power quality of other agents connected to the grid. Together with the tool, it is also proposed a protocol to be followed for the issuance of the connecting opinion. Figure 1 shows the suggested protocol for issuing distributed generation access analysis using the tools of Hosting Capacity and Individualized Connection Opinion, represented by light blue the steps related to simulation via software, which are automatic, and by dark blue steps the steps which are of the responsibility of the company.

The process begins when an access request arrives at the distributor, consisting of the power of the generation and the coordinates from which it will be located. The next step is to identify in the company's registration records the feeder(s) to which this generation can be connected and then use SINAPgrid to simulate the necessary electrical networks. The next step is to use the result information of the Hosting Capacity calculation to determine whether it is less than the power intended by the generation. If it is so, then the process must terminate, and the connection should be denied. This step is important for many requests to be processed without the need of thorough analysis.

If the result of the calculation is higher, that is, indicating that the network can accommodate this generation, the process for issuing the individualized connection opinion begins, which occurs as automatically as possible. Whitin this process, the connection will be simulated in the network, being able to carry out studies of maximum and minimum load, with and without generation, and also with maximum and minimum generation. For these studies, it will be verified if there was a transgression of any of the criteria of interest to the process, which have already been detailed in Section II. If there is no transgression, the connection is approved.

Otherwise, reinforcements must be carried out on the network so that it can accommodate the new generation. The reinforcements to be carried out will depend on the planner, and their costs and impact on network losses will be accounted for in the calculation of the Global Cost. For each solution alternative of the transgression, the problem will be assigned a Global Cost and then, after the simulation of all scenarios, the alternative with the lowest Global Cost will be determined, and the opinion will be approved.

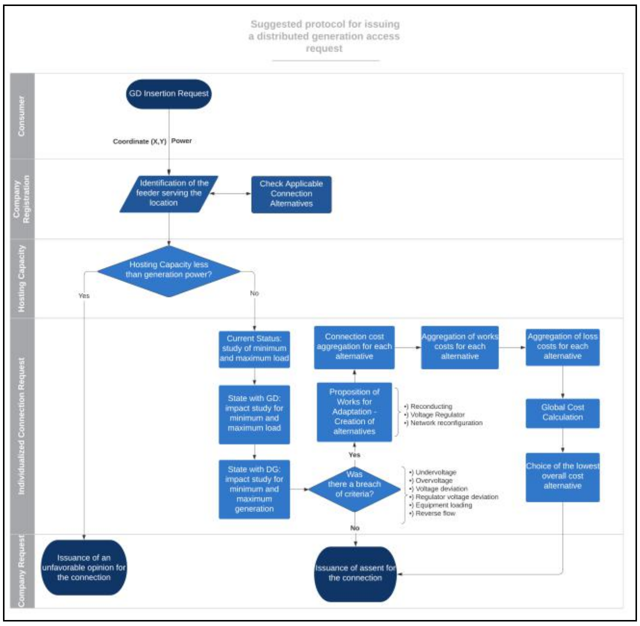

Fig.1: Suggested protocol for issuing a distributed generation access opinion.

The specifications and assumptions adopted in the automated opinion issuing tool were as follows:

- The tool is flexible for analyzing connection requests for mini generation and microgeneration [1].
- The tool works concurrently, as a module of the planning tool of the SINAPgrid power grid simulation platform.
- The implementation of the module should be such that the planner has flexibility over changes in the network, while the process of issuing opinions is

automated enough to quickly meet the high demand for the issuance of these opinions.

- The module should be able to provide an estimate of what the lowest overall cost of each alternative is, either rejected or not and, either, owning works or not.
- The connection of the accessor cannot bring fall to the quality of the energy provided by the distributor. Thus, the connection alternative to be defined should be the one that will bring less risk of damage to all agents connected to the electricity grid.
- About the quality of energy during the operation of the accessing generation, the injected power will have a standard power factor value equal to 1.00 and can be changed depending on the planner.
- It is the responsibility of the accessor to ensure that the limits of harmonic distortions are not violated.
- For the calculation of the minimum overall cost, modular standard costs will be adopted that will be used in cost estimation calculations. The planner may change these values if it deems it necessary. A value for the cost of losses (R$/MWh) should also be defined, which may be changed.

V. CASE STUDY

To test the application of the tools and protocol developed, we studied the connection of a photovoltaic generation of 1.5 MWp in a real electrical network belonging to a Brazilian distribution utility.

The first step was to identify the feeder to which this generation would be connected to verify whether it would be able to comport it, by analyzing the result of its Hosting Capacity, as shown in Figure 2 and Figure 3, and the first figure presents the result for the entire feeder and the second only for the vicinity of the bar to which the generation will be connected, bar B_516.

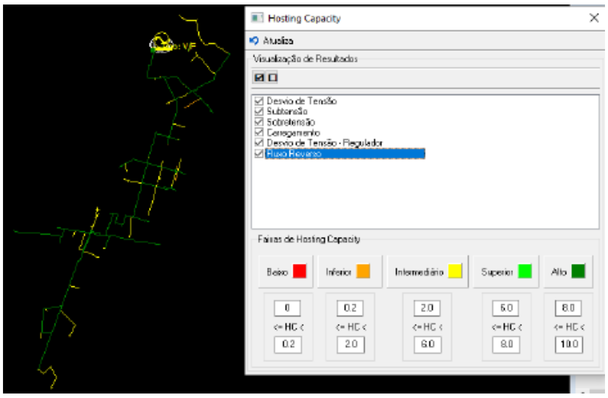

Fig.2: Hosting Capacity result for the feeder to which the generation would be connected.

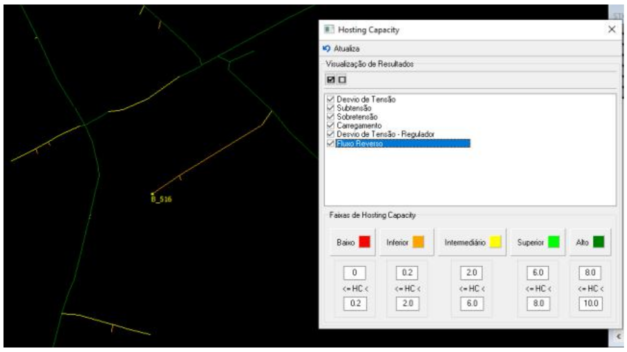

Fig.3: Hosting Capacity result near the bus to which the generation will be connected.

From the figures it is possible to note that the network will be able to support the generation of 1.5 MWp, however, if the generation was greater than 2.0 MWp, this connection request should be rejected, because the Hosting Capacity for a DG in that region was classified as "Inferior", that is, with a value between 0.2 and 2 MW.

Thus, the next step is that of the individualized connection opinion, according to Figure 4, in which it was verified that there was no transgression of any of the selected criteria, which means that the opinion can be approved, with the knowledge that the connection of this generation will not cause damage regarding the quality of the electricity network.

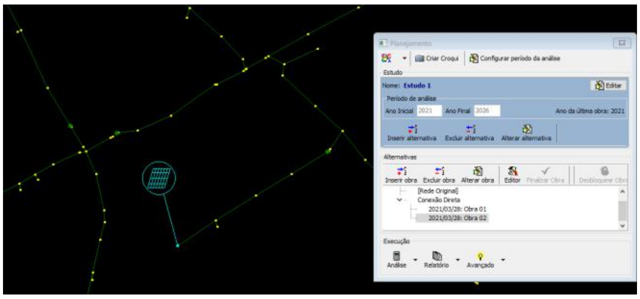

Fig.4: DG simulation to be evaluated in the individualized connection report

However, the network situation before the generation connection presented voltages close to the lower limit of what would be acceptable, the module indicated this, according to Figure 5, and, for this test case, the behavior of a planner who chose to solve this situation was simulated by evaluating the impact of two different works: the insertion of a voltage regulator and the reconductor of the network.

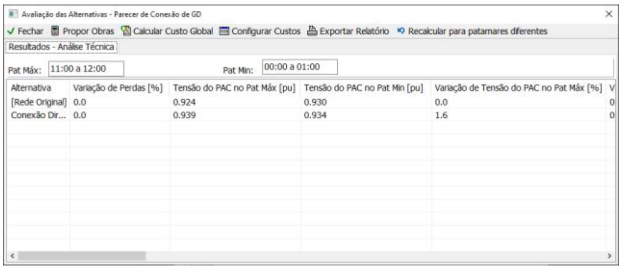

Fig.5: Results of the evaluation of the generation connection alternative.

For the evaluation of the Global Cost, the costs presented in Figure 6 were used, the results of Global Costs are presented in Figure 7, in which it is clear that for this test case, the connection alternative associated with the reconductoring should be the chosen alternative.

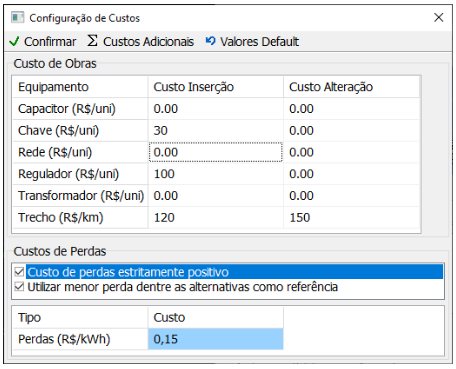

Fig.6: Costs for alternatives.

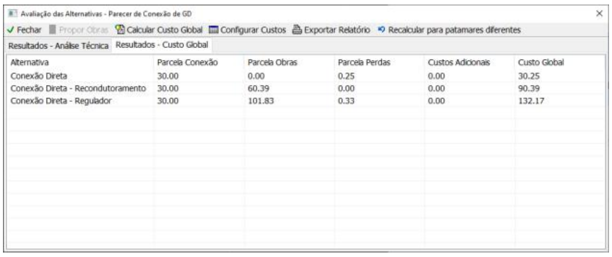

Fig.7: Overall cost calculation result.

This test case presents a characteristic of the great importance of the tool that is to automate several steps of the process without compromising the expression of the results regarding the quality of energy and presenting sufficient flexibility for the action of the planner.

VI. CONCLUSION

This paper presented the studies and specifications of the development of a computational platform for distributed generation connection evaluation that uses the concept of Hosting Capacity and automated individual analysis of the connection.

According to what was presented in this article, it is understood that the distributed generation connection should be carried out carefully and judiciously in order to not cause problems for the power quality of distribution networks. An agile and satisfactory way to ensure this is through computational tools to simulate the impact that generation shall have on the network. The computational platform presented in this paper proved to be able to provide fast and satisfactory results, assisting the utility in this process by using the concept of Hosting Capacity and the individual analysis of the connection. Another contribution is the suggested protocol for issuing distributed generation access analysis using the tools of Hosting Capacity and Individualized Connection Opinion that shall assists the utilities in the evaluation of the large number of connection requests with which one must deal.

REFERENCES

[1] Resolução Normativa Nº 482, de 17 de Abril de 2012. Agência Nacional de Energia Elétrica – ANEEL
[2] S. M. Ismael, S. H. E. Abdel Aleem, A. Y. Abdelaziz, e A. F. Zobaa, "State-of-the-art of hosting capacity in modern power systems with distributed generation", Renewable Energy, vol. 130, p. 1002–1020, jan. 2019, doi: 10.1016/j.renene.2018.07.008.
[3] M. Rossi, G. Vigano, e D. Moneta, "Hosting capacity of distribution networks: Evaluation of the network congestion risk due to distributed generation", in 2015 International Conference on Clean Electrical Power (ICCEP), Taormina,

Italy, jun. 2015, p. 716–722, doi: 10.1109/ICCEP.2015.7177570.

[4] Procedimentos de Distribuição de Energia Elétrica no Sistema Elétrico Nacional – PRODIST - Módulo 8 – Qualidade de Energia Elétrica. Agência Nacional de Energia Elétrica – ANEEL

[5] Resolução Normativa Nº 414, de 9 de Setembro de 2010. Agência Nacional de Energia Elétrica – ANEEL

[6] A. Dubey, S. Santoso, e A. Maitra, "Understanding photovoltaic hosting capacity of distribution circuits", in 2015 IEEE Power & Energy Society General Meeting, Denver, CO, USA, jul. 2015, p. 1–5, doi: 10.1109/PESGM.2015.7286510.

[7] M. Rylander, J. Smith, e W. Sunderman, "Streamlined Method for Determining Distribution System Hosting Capacity", in 2015 IEEE Rural Electric Power Conference, Asheville, NC, USA, abr. 2015, p. 3–9, doi: 10.1109/REPC.2015.11.

[8] S. M. Ismael, S. H. E. Abdel Aleem, A. Y. Abdelaziz, e A. F. Zobaa, "State-of-the-art of hosting capacity in modern power systems with distributed generation", Renewable Energy, vol. 130, p. 1002–1020, jan. 2019, doi: 10.1016/j.renene.2018.07.008.

[9] Procedimentos de Distribuição de Energia Elétrica no Sistema Elétrico Nacional – PRODIST - Módulo 3 – Acesso ao Sistema de Distribuição. Agência Nacional de Energia Elétrica – ANEEL