DG IMPACT EVALUATION ON LV DISTRIBUTION GRIDS USING AMI DATA: A BRAZILIAN CASE STUDY

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ABSTRACT

Distributed Generation (DG) has substantially increased around the world and represents an important means of developing renewable energy power generation. The current levels of DG penetration in the Brazilian distribution networks do not cause significant impact on MV grids. However, the LV networks could face negative impacts, especially on voltage. Therefore, this paper presents how AMI data could improve DG impact studies in LV distribution networks. The results obtained using AMI data were compared with traditional methods used in distribution for load allocation. The distribution feeder and the AMI information were obtained from the Smart City Búzios project, implemented in Búzios, in the state of Rio de Janeiro, Brazil. The analysis on voltage were performed using the OpenDSS software. The results show that the traditional load allocation techniques could overlook excessive voltage rise. Therefore, AMI could provide important data to perform DG impact studies on LV distribution networks.

INTRODUCTION

Distributed Generation (DG) has substantially increased around the world and represents an important means of developing renewable energy power generation. In Brazil, the National Electric Energy Agency published the rule 482/2012 in order to establish the general conditions for access of mini and micro distributed generation for the grid [1]. Among DG technologies, solar photovoltaic (PV) plays a major role due to advances in PV technology, combined with decreasing capital costs and subsidies. Currently, the PVDG adoption have grown significantly in Brazil, representing more than 95% of the DG units connected in 2016 [2]. The current levels of PVDG penetration in the Brazilian distribution networks do not cause significant impact on medium voltage (MV) grids. However, the low voltage (LV) networks could face negative impacts, especially on voltage.

In fact, the voltage regulation is one of the most import issues in DG impact evaluation on the distribution network. The problem is to keep the steady state voltage levels in all bus within the permissible limits. In countries with higher PVDG penetration, such as Germany, it is noted that the main challenges of voltage regulation arise in the secondary distribution networks [3].

Although the utilities need to evaluate the DG impact at LV grids, the companies traditionally face a lack of technical information about consumers. The load curve, for instance, is an important information when considering intermittent generation, such as PV, but it is generally not available for a DG study. The application of Advanced Metering Infrastructure (AMI) in distribution networks could benefit the DG integration, since it provides data for planning, analysis and DG operation.

Therefore, this paper presents how AMI data can improve DG impact studies in LV distribution networks. The load curve obtained from 15-minute demand readings collected by AMI data were compared with traditional methods used in distribution for load allocation. The distribution feeder and the AMI information were obtained from the smart meters installed in the Smart City Búzios project, implemented in Búzios, in the state of Rio de Janeiro, Brazil. A 75 kVA distribution transformer was chosen to demonstrate the difference among the load curves obtained by the transformer rated power, monthly energy consumption and AMI data. A limit of DG penetration in the transformer was calculated, considering the LV voltage limits. The data used for DG, substation consumption, and load curves are from July 2016. The analysis on voltage were performed using the OpenDSS software. The results show that load curves obtained by traditional allocation methods could overlook negative impacts of PVDG on LV distribution networks.

SMART CITY BÚZIOS PROJECT

The city of Búzios is supplied by a 69/13.8 kV substation with two 25 MVA transformers. The feeder BUZ05 is one of the four circuits connected to the substation’s transformer T2 and it supplies the area shown in Figure 1. The nominal MV and LV are, respectively, 13.8 kV and 220/127 V. The feeder BUZ05 has approximately 210 distribution transformers. The transformers that are not private aggregate a total of 3,044 LV clients, of which 71% have smart meters installed.

The load data obtained for the BUZ05 feeder analysis were the substation current and voltage measurements, the clients’ consumption readings used for billing and the consumption records collected every 15 minutes by AMI. The analyses were undertaken considering the load conditions from July, 2016. In Brazil, generally, the load is heavier on summer. Therefore, July was chosen because is a winter month, where it is expected that voltage rise due DG would be higher. Additionally, Búzios is a touristic place, which makes load on July considerably lower than on the summer.

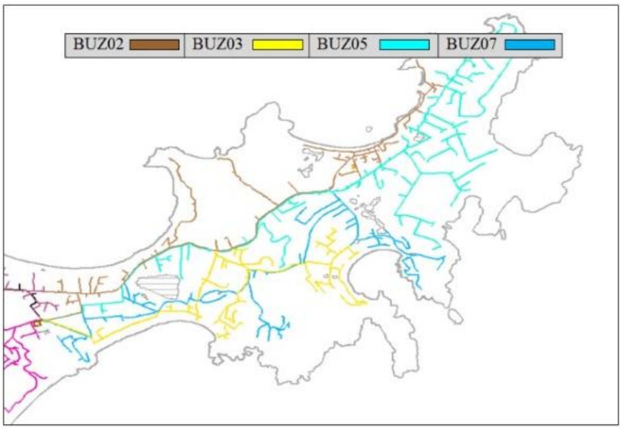

Figure 1. Feeders for the Smart City Búzios Project area.

The curve representing the active power demand at the substation for this month is shown in Figure 2.

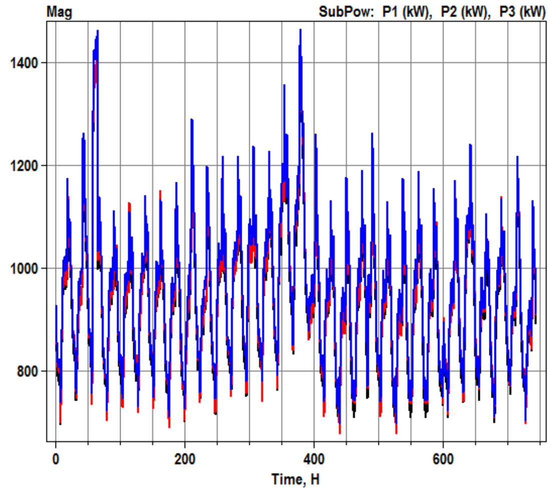

Figure 2. The active power demand at the substation, per phase, in July, 2016.

In Figure 3, the feeder voltage profile is presented for the lowest load conditions in July.

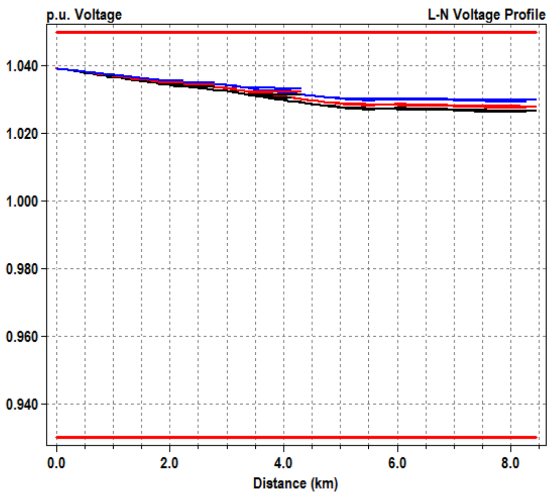

Figure 3. BUZ05 feeder voltage profile for lowest load in July.

Distributed Generation

More than a dozen DG systems were installed within the scope of Smart City Búzios project, considering both wind generation and solar photovoltaic systems. The installed photovoltaic systems used were mostly polycrystalline panels, except one of the Research and Monitoring Center (RMC), where thin-film panels were adopted. The rated power of the PV systems were generally close to 5 kWp. The technical specifications for each DG system are detailed in [4]. In Figure 4, one can observe both polycrystalline and thin-film DG systems installed at the RMC, in Búzios.

Figure 4. Solar photovoltaic generation systems installed at the RMC, in Búzios

METHODOLOGY

The DG penetration entails the need of new methodologies and studies for the analysis of electrical distribution networks [5-6]. Several commercial computational tools present modelling and simulation capabilities consistent with the most recent requirements of distribution network analysis [7]. In this work, the OpenDSS software is used to carry out DG impact studies.

The OpenDSS (The Open Distribution System Simulator) is a free simulation software developed by EPRI (Electric Power Research Institute) with extensive electrical modelling and calculations for distribution system analysis [8]. For these reason, the Brazilian Electricity Regulatory Agency (ANEEL) discusses with the agents of the sector the possibility of adopting the computational tool as a standard for technical losses calculation [9].

Two traditional methods of load allocation available on the OpenDSS were used to perform the proposed analysis. The first one is based on the transformer rated power, in kVA, and the second one uses the customers' monthly kWh metered for billing [10]. OpenDSS uses an iterative method to perform the load allocation, in which the user needs to report the current at the beginning of the circuit and the nominal power or the consumption per distribution transform. The user can also report the current at different points in the circuit to a more accurate load allocation. For the BUZ05 feeder studies, the reported currents were only those of the substation and both forms of load allocation were applied.

Therefore, the feeder BUZ05 was simulated considering the three allocation methods. The secondary network of a three phase 75 kVA transformer was modelled in OpenDSS in order to evaluate the impact of PVDG. Hence, for each load curve the PVDG penetration was increased until the voltage violates the upper voltage limit, which is 133 V, phase to neutral, in Brazil for the 200/127 V rated voltage level. The DG penetration was raised considering the connection of an additional 5 kWp PV systems in the LV network, since it is a PV system rated power usually connected by residential customers in Brazil. Therefore, it is possible to compare how much PVDG could be connected to the LV grid considering the load curves obtained by the three allocation methods.

Modelling the Distribution Network of Búzios

The data obtained for the Búzios' feeder allow the complete modelling of the primary 13.8 kV network, enabling the impact assessment of the installed DG systems' MV network. Hence, the places where distribution transformers were installed were modelled as loads. The secondary network of a 75 kVA transformer was modelled to analyse the PVDG impact. The individual load shapes obtained by AMI data were aggregated to compare the results with the other allocation methods. The secondary is a 220/127 V radial network with a 3x70 mm^2(50 mm^2) quadraplex copper cable line.

In some cases, secondary network data were collected so as to enable the LV network behaviour assessment.

The loads representing the distribution transformers were modelled following the ANEEL recommendations [11] for the technical losses determination. Thus, the ZIP load model was used, considering that connected loads are composed by 100% of the constant impedance model for the reactive portion and by 50% of the constant power model and 50% of the constant impedance model for the active power portion.

One of the assumptions also taken was to consider all the system's three-phase loads as balanced, once it was not informed the load distribution per phase for each distribution transformer. The distribution transformers are mostly three-phase with rated power from 30 kVA to 300 kVA. There are few single-phase branches feeding single-phase transformers.

Lastly, a standard 0.91 power factor was used for all the distribution transformers that had not had their power factor measured. Such value is an average value among the average values and is also in accordance with the values verified in literature [10], [12].

Load Allocation Methods

Three methods were applied for the determination of the load curve for each distribution transformer:

a) Transformer kVA allocation: is a traditional methodology in which the substations measurements are used and the load allocation is undertaken as a function of the distribution transformers' rated power. In spite of not being an accurate method, it is of simple application and uses available data;

b) Monthly usage allocation: is a methodology in which the load allocation is undertaken as a function of measured consumption for monthly billing aggregated by transformer. Is a widely applied technique and that usually shows better results than the allocation method by transformer kVA;

c) AMI data allocation: gives the load curve per customer in 15 minutes intervals. The meters' readings are done remotely. It is an accurate technique that, however, depends on the complete smart metering infrastructure. In the case of the BUZ05 circuit, the smart meters were not installed in all feeders' clients. Thus, a the LV analysis were performed for a transformer with smart meters installed for all the customers.

RESULTS

In this work are compared different load allocation approaches and how this may interfere in DG impact assessments, considering the secondary network voltage limits. The results were obtained for July, 2016, and with a power generation curve based on the thin-film PV system at the RMC.

In Figure 5, concerning the 75 kVA transformer, one can observe that allocation based on transformer kVA assigns a higher load to the transformer, whereas the allocation based on AMI shows a generally lower load when compared to the others. Moreover, as opposed to AMI allocation, both the transformer kVA and monthly usage allocation approaches preserve a load curve with the behavior equivalent to that of the substation, in which local load variations are not represented.

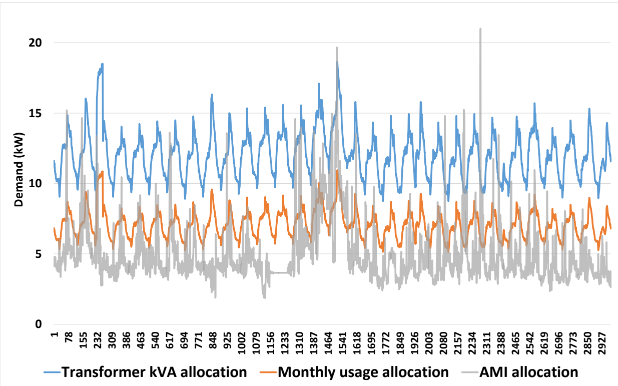

Figure 5. Transformer load curve obtained by nominal power, consumption and AMI allocation approaches.

As for the voltage PVDG impact, considering the curve obtained by transformer kVA allocation, the transformer admits to be connected to up to four 5 kWp PVDG systems with no voltage elevation above 133 V. In the case of the curve obtained by consumption, three 5 kWp PVDG systems can be installed with no voltage violation whereas the AMI allocation case, two systems are allowed. Therefore, there are penetration levels of PVDG considered as acceptable for transformer kVA and monthly usage allocation methods that could cause excessive voltage rise, considering the real load curve obtained by AMI.

The voltage curves on the secondary transformer are represented in Figure 6 and in Figure 7, considering the allocation by AMI, to show the voltage violation caused by connection of PVDG. The voltage in Figure 6 were obtained for a penetration scenario of two 5 kWp PV systems and Figure 7 represents the voltage for three 5 kWp PV systems penetration scenario. Both fi

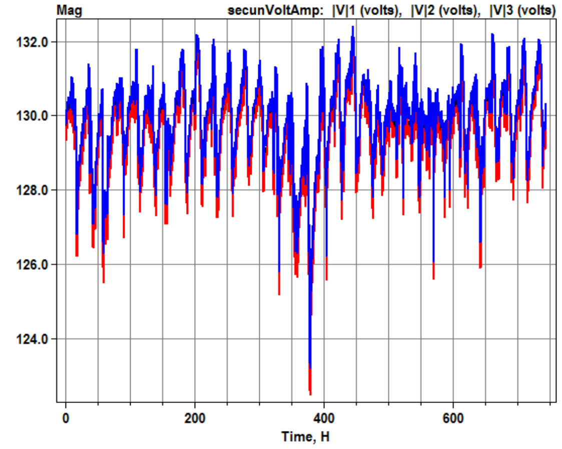

Figure 6. Voltage for the connection of two 5 kWp PV systems with AMI allocation.

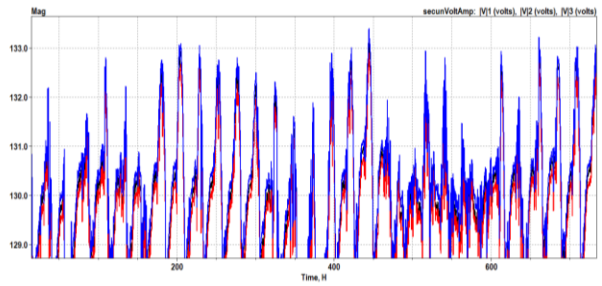

Figure 7. Particularity of the voltage curve for the connection of three 5 kWp PV systems with AMI allocation.

The undertaken analysis shows that the assessment impact of DG on secondary networks voltage regulation can be considerably altered, in case the load is not appropriately characterized.

CONCLUSIONS

In this paper real distribution network and AMI data, available on the Smart City Búzios project, were modelled on OpenDSS to analyse how the load characterization methods could affect PVDG impact studies, considering LV networks.
The results show that the traditional load allocation techniques could overlooks excessive voltage rise, leading to accept PVDG connection that could cause voltage limit violation in reality. The analysis was performed for a winter month, when the load is reduced considerably. Hence, depending on the characteristics of the feeder, it is also possible that there are cases where more DG could be connected than the traditional study indicates. The results demonstrates the importance of detailed and reliable load data to correctly evaluate DG impact on LV distribution networks, especially for Brazil were PVDG penetration is growing and distribution companies generally do not perform detailed LV impact studies. Finally, further work will analyse how partial availability of AMI data could improve DG studies for customers billed by the traditional electronic or electromechanical energy meters, which are still common in Brazil.

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