19th International Conference on Renewable Energies and Power Quality (ICREPQ'21)
Almeria (Spain), 28th to 30th July 2021
Renewable Energy and Power Quality Journal (RE&PQJ)
ISSN 2172-038 X, Volume No.19, September 2021

The behavior of a low voltage distribution network with crescent photovoltaic generation penetration and presence of energy storage elements

R. M. Leite, J. V. Souza, E. N. Asada, M. Oleskovicz
Department of Electrical and Computer Engineering – University of São Paulo – USP/EESC
rafaelleite@usp.br, jonas.villela@usp.br, easada@usp.br, olesk@sc.usp.br

Abstract

This paper aims to examine the increasing integration of distributed energy resources in the low voltage distribution grid. Considering the current assimilation pattern of distributed photovoltaic generation in Brazil, there is a deterioration of specific indices related to the electric power quality, such as overvoltage and voltage unbalance. In this sense, a survey of these problems, the severity assessment via simulation of a real system and the proposal of improvement in the associated indexes using energy storage devices are made. The resulting analyzes contemplate both the current reality of growth in the distributed photovoltaic generation and the joint integration of these generators with energy storage systems, thus enabling a comparison of results focusing on the electricity grid impacts. The proposed technique has shown an improvement in the network's operation, reducing the aggravating factors in the quality and increasing the local consumption of the energy generated locally..

Methodology

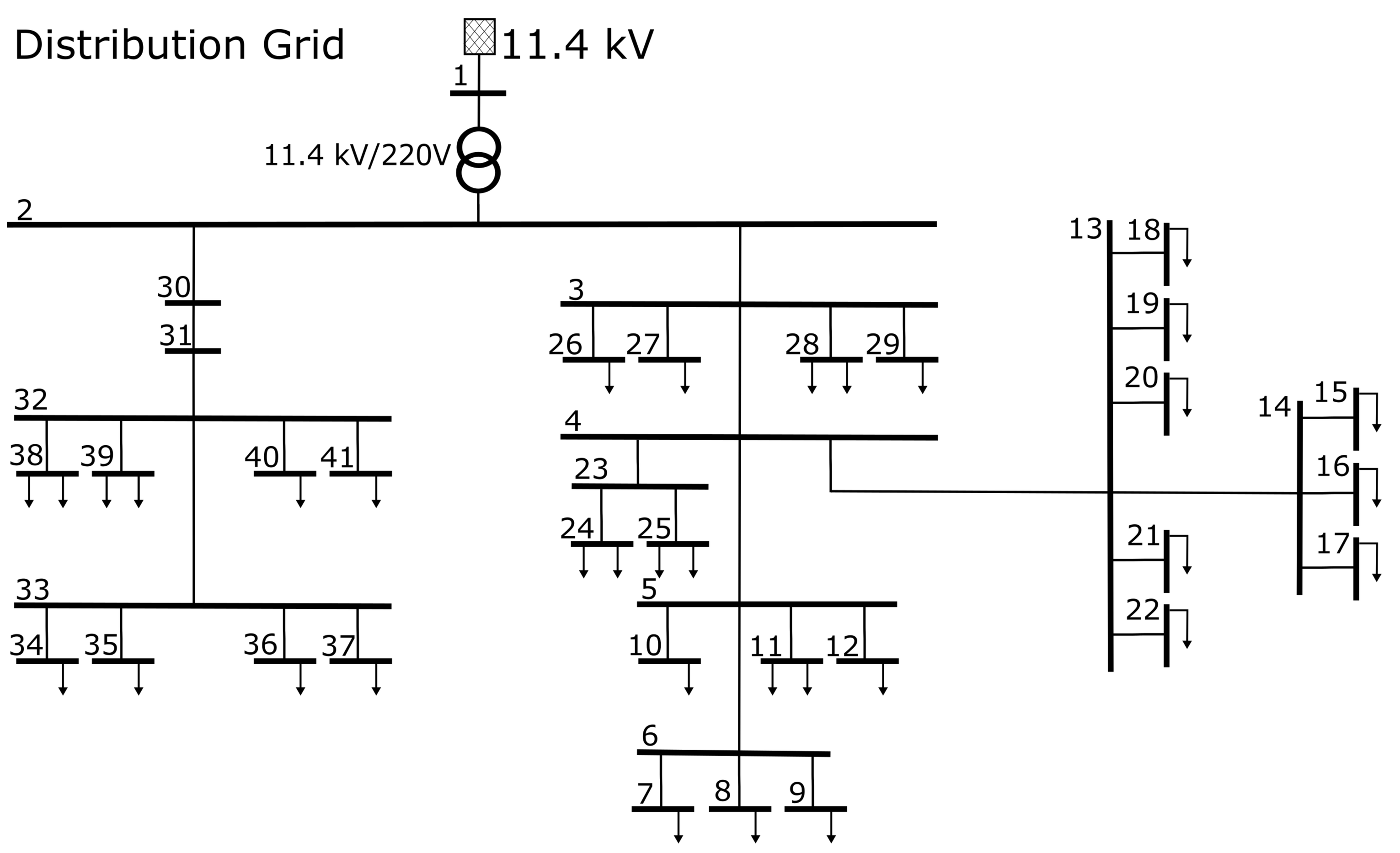
It is proposed the consumption profiles smoothing, combining residential DG-PV (Photovoltaic Distributed Generation) with the application of ESS (Energy Storage System), represented by a battery bank. The aim is to balance periods of high generation and consumption, ensuring that the surplus of energy generated can be used at a more opportune moment, preventing it from being injected into the network.

The simulations that make up this study are divided into three phases. In the first phase, a test distribution system is analyzed. During the second phase, the presence of DG-PV is progressively increased until all consumers behave as Prosumers. In the third phase, distributed ESSs are added and allocated to each Prosumer. Still In the third phase, distributed storage units are disregarded, which will give place to a single and concentrated ESS located at the beginning of the feeder.

Essentially, each of these steps has a specific purpose. First of all, it is necessary to evaluate the original test system's performance, enabling a comparison parameter for all other cases. Then, the impacts of the continuous integration of DG-PV in the low-voltage distribution network are studied. To mitigate the possible problems caused by the previous scenario, ESSs are inserted as individual resources in each residential installation or as a larger concentrated ESS that handles the entire network.

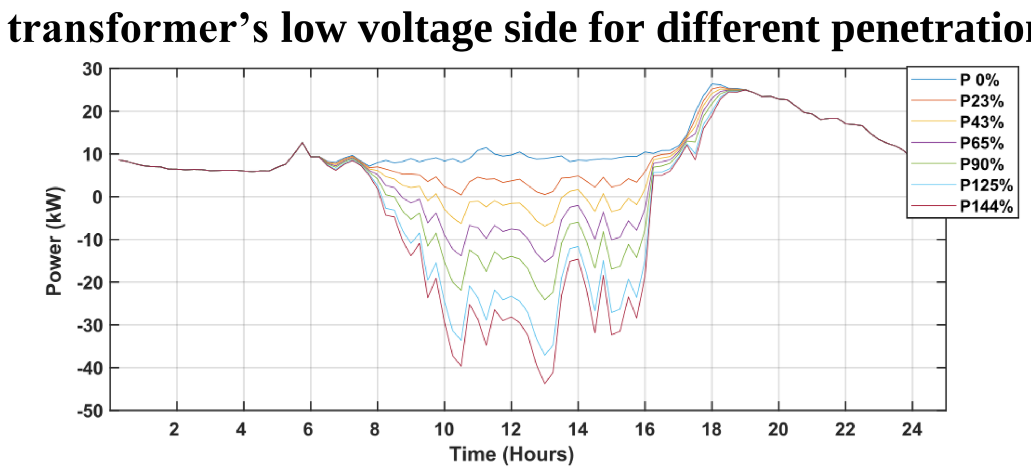
The DG-PV was calculated for each of the 34 consumers connected to the test system. The penetration percentage level was calculated considering the nominal PV power and the 45 kVA distribution transformer's as reference.

Test distribution grid

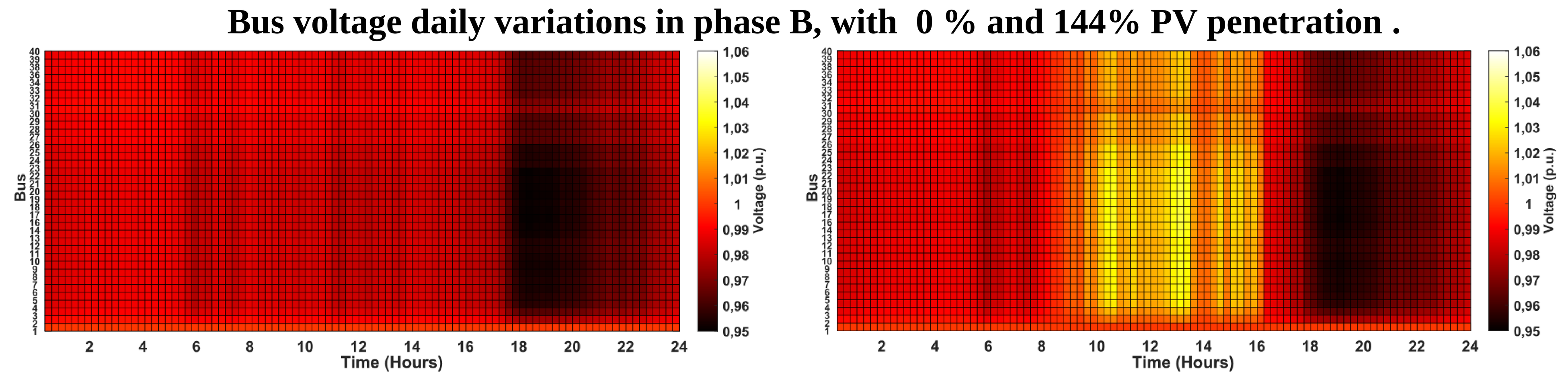


Results

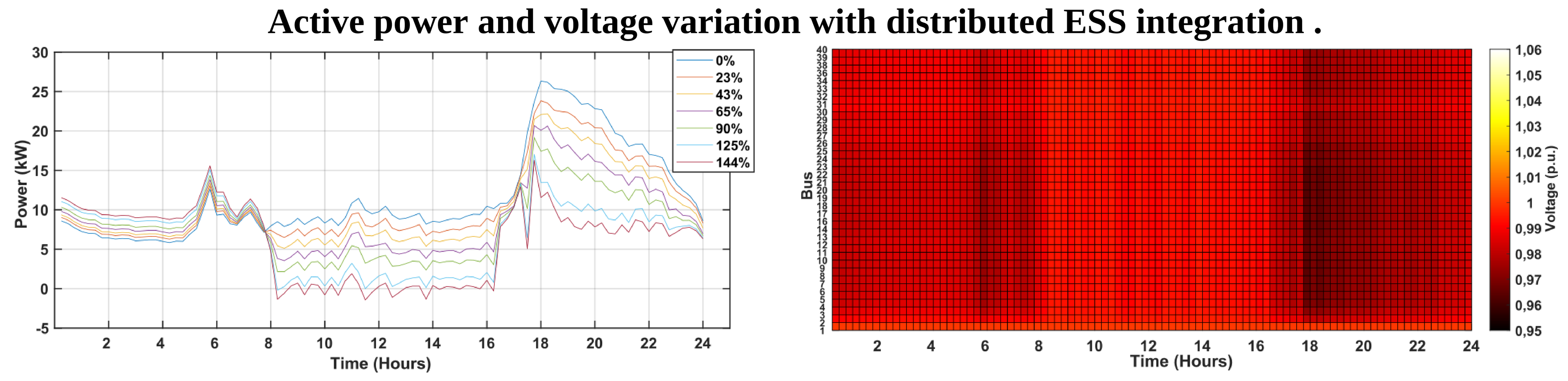
Active power on the transformer's low voltage side for different penetration levels of the DG-PV.



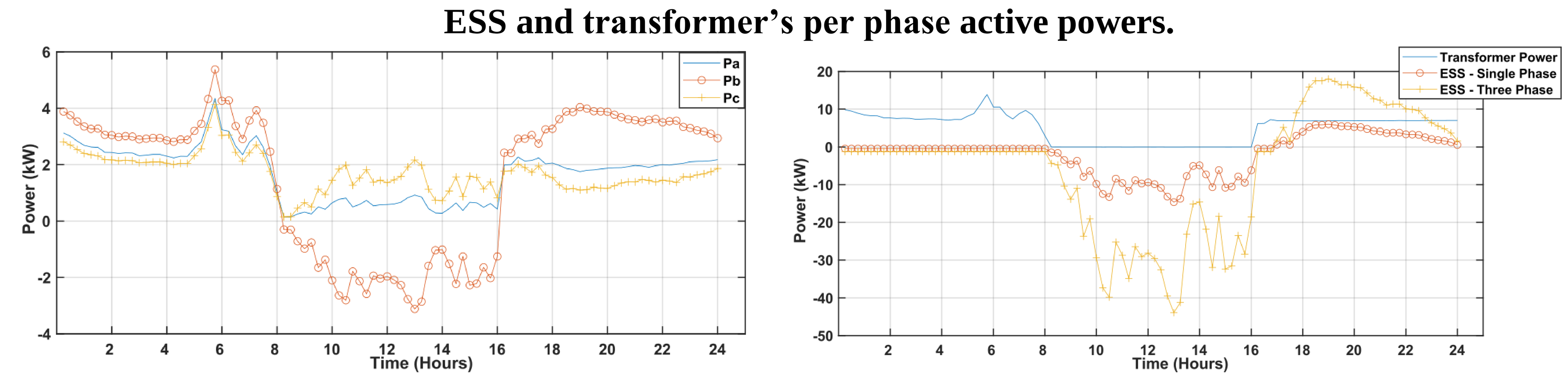
Bus voltage daily variations in phase B, with 0 % and 144% PV penetration .



Active power and voltage variation with distributed ESS integration .



ESS and transformer's per phase active powers.



Impact indicators on network operation.

Indicators		Original (0%)	DG-PV (144%)	DG-PV-ESS (144%)	Focused PV-ESS (144%)
Variation (%)	V_{min}	-4.94	-4.88	-3.69	-3.54
	V_{max}	0	3.92	0	1.15
	FD_{max}	0.44	0.57	0.29	0.69
Losses (kW)	Line	9.12	16.59	4.8	12.79
	Tran.	8.13	14.82	4.28	3.86
	Total	17.26	31.42	9.08	16.65

Conclusion

The integration of ESSs, both distributed and concentrated, improves the operation of a high penetration grid-connected DG-PV. Both the maximum and the minimum bus voltage variations measured are reduced. There is also a considerable easing of total losses in comparison to the original network configuration and with the usual DG-PVs penetration. Improvements are also observed in the voltage unbalance (FD%) since voltage variations are reduced. However, in the concentrated ESS case, once it is integrated into the system by a frequency inverter (as well as all distributed resources), its output power is always the same for the three phases. As the consumption of the residential units connected to the network is not balanced between the conductors, the ESS control cannot match these values. Therefore, there will still be a considerable reverse active power flow in the transformer and the FD% deterioration in some points.

São Carlos School of Engineering
Department of Electrical and Computer Engineering
University of São Paulo
São Carlos, São Paulo, Brazil, 13566-590

Sponsor: