277

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A First Approach on the Impact of Distributed Generation and Falt Impedance on Studies on Voltage Sags

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Abstract

An analysis of the distributed generation (DG) and fault impedance on studies of voltage sags caused by system faults is presented. The simulation of 62 case studies of phase-to-ground faults on 13.8, 69, 138 and 230 kV transmission lines were performed and the voltage of a 380 V sensitive industrial busbar client was monitored. These lines are part of the electrical system of the city of Goiania, Brazil. For each case study, different fault positions and impedance fault were simulated by considering different DG levels connected to the consumer busbar. Long-term simulation scenarios were obtained by the Monte Carlo method and analyzed based on their cumulative distribution functions and probability density curves of voltage sags. This is one major contribution of this work.

1. Introduction

In an evolving world, electrical loads and processes demand sources of power that are free from distortion and within certain patterns. Voltage sags have been the main source of problems that affects industrial consumers [1], [2], [3]. Their causes include short-circuits (i.e., faults), transformer energization, motor starting and sudden load changes. However, short-circuits are the cause of the most severe voltage sags in transmission and distribution networks [1]. There are many factors that influence voltage sags and some of them have received considerable attention from the researchers as, for example: the fault characteristics (location, type, impedance and fault Distribution), pre-fault voltage, fault rate, protection system, reclosing system and the system generation level [2]. Another area of emerging interest for research is distributed generation (DG). Any power source that is directly connected to the distribution grid or end user system can be defined as DG [3]. These kinds of sources have been re-emerging in the entire world, mainly due to environmental questions. Besides, DG may be seen as a solution for many power quality problems, such as those related to voltage sags [2]. This study considers that the DG stays connected to the system when a fault occurs.

2. Methodology

The industrial busbar consumer monitored is described in the top of Fig. 1 as “Client C busbar 9112”.The end-user’s transformers are included in the model. Short-circuits are simulated in all lines of the grid and vulnerability areas are not considered. The position of the fault is located along each line from zero to 100 % in steps of 1 %. For each short-circuit position the impedance is assumed to be null, and the pre-fault voltages are assumed to be 1 p.u.. Another specific computational tool was implemented in MATLAB in order to manipulate the simulation results. This tool performs a Monte Carlo analysis and treats data generated by ANAFAS-GUI for each level of DG. The Monte Carlo algorithm is described as follows:
1. Define the busbar to be analyzed; **2.** Define the number of scenarios for simulation;
3. Previously define the number of faults in the grid over one year, according to the fault rate in each system line. This procedure resulted in approximately 113 random faults per year; **4.** For each year, randomly take the faulted line (FROM-bar and TO-bar). This line has any order between 1 and 62. Then randomly take an integer which represents the fault position. This last task is repeated 113 times, resulting in 113 voltage values at end-user busbar. These values are then filtered in order to record only the voltage sag representing values;
5. After the previous item, the order of the year is incremented by one, and item 4 is repeated until the number of years reaches the total of user defined years.
A second study shows the average number of voltage sags, obtained for an end-user busbar, according to the voltage sag magnitude and the third study shows the impact of the fault impedance on the number of voltage sags for th same faults in the system.

$$N_{sag} = \frac{1}{N_{years}} \sum_{i=1}^{N_{years}} X_i$$

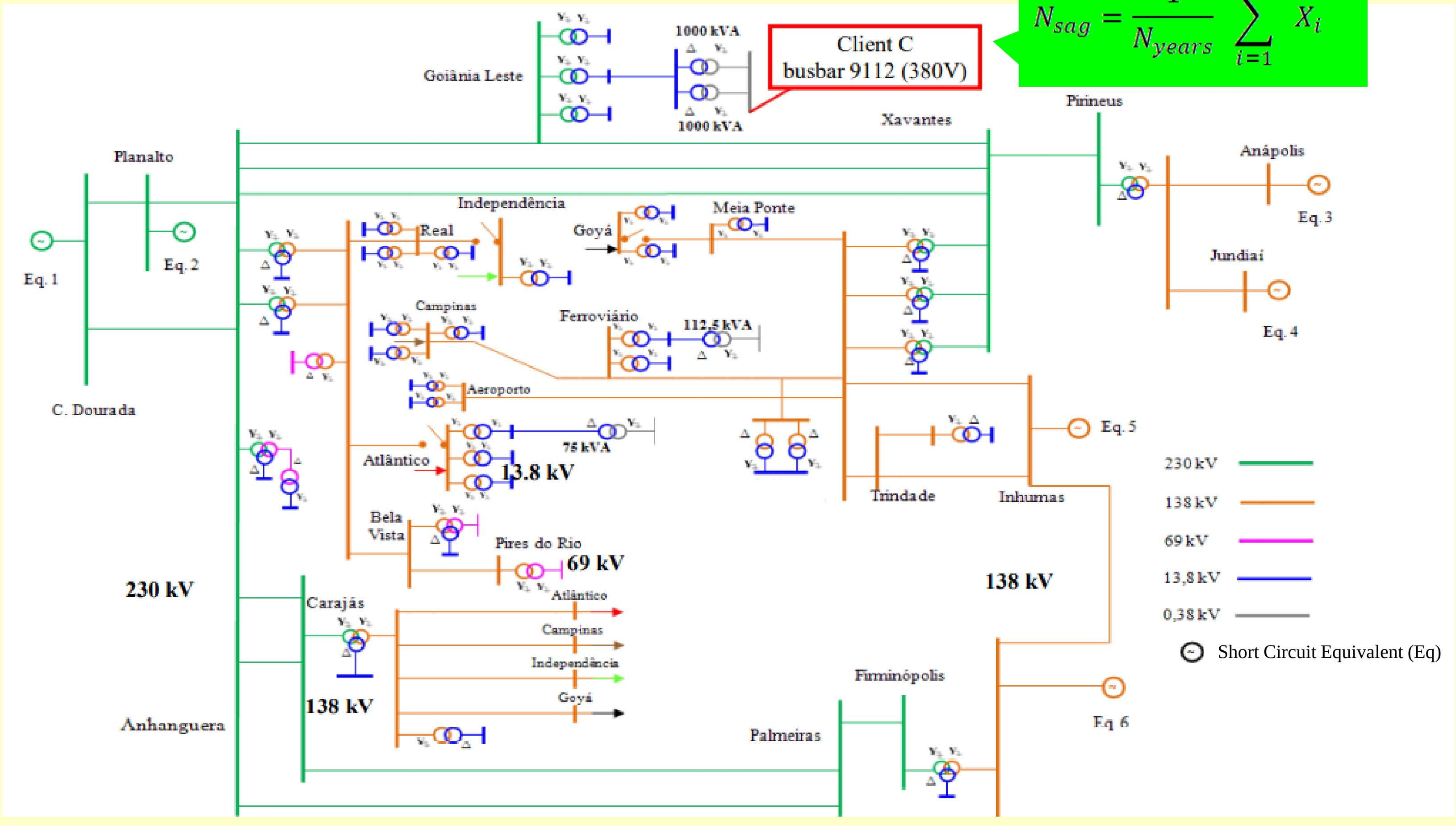

Figure 1 – Goiania electrical grid.

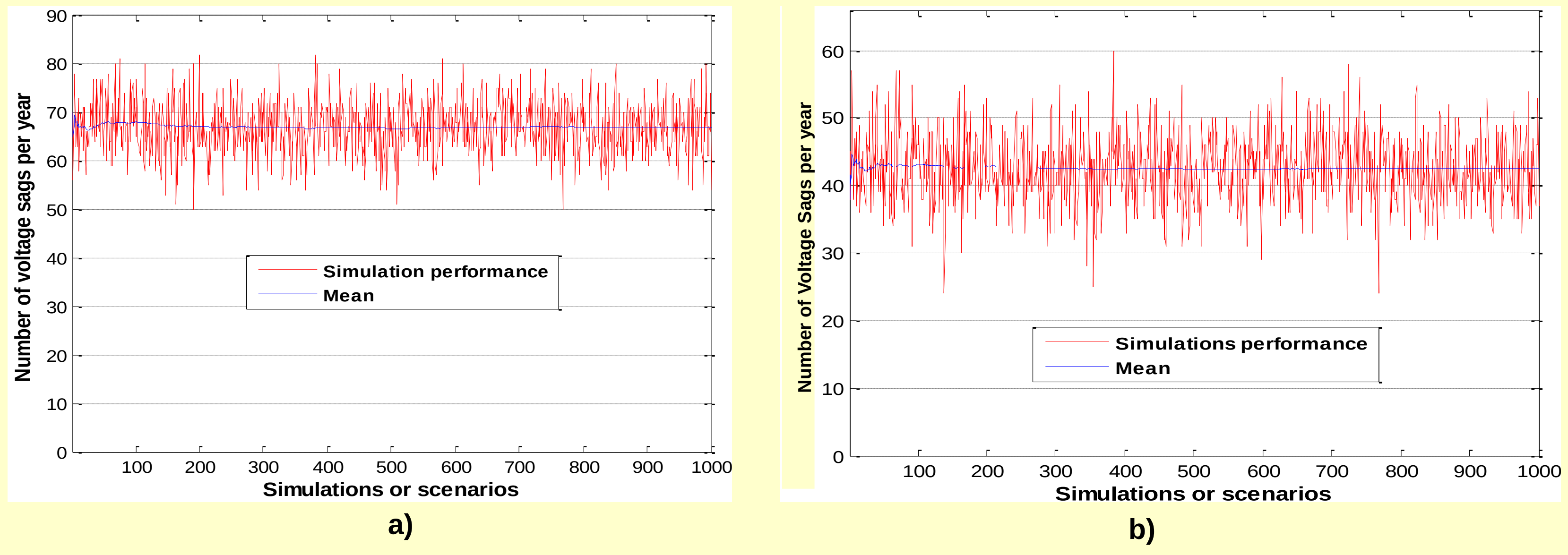

Fig. 2. Simulation performance and average number of voltage sags at busbar 9112 a) for 0 kVA ; b) for 4500 kVA.

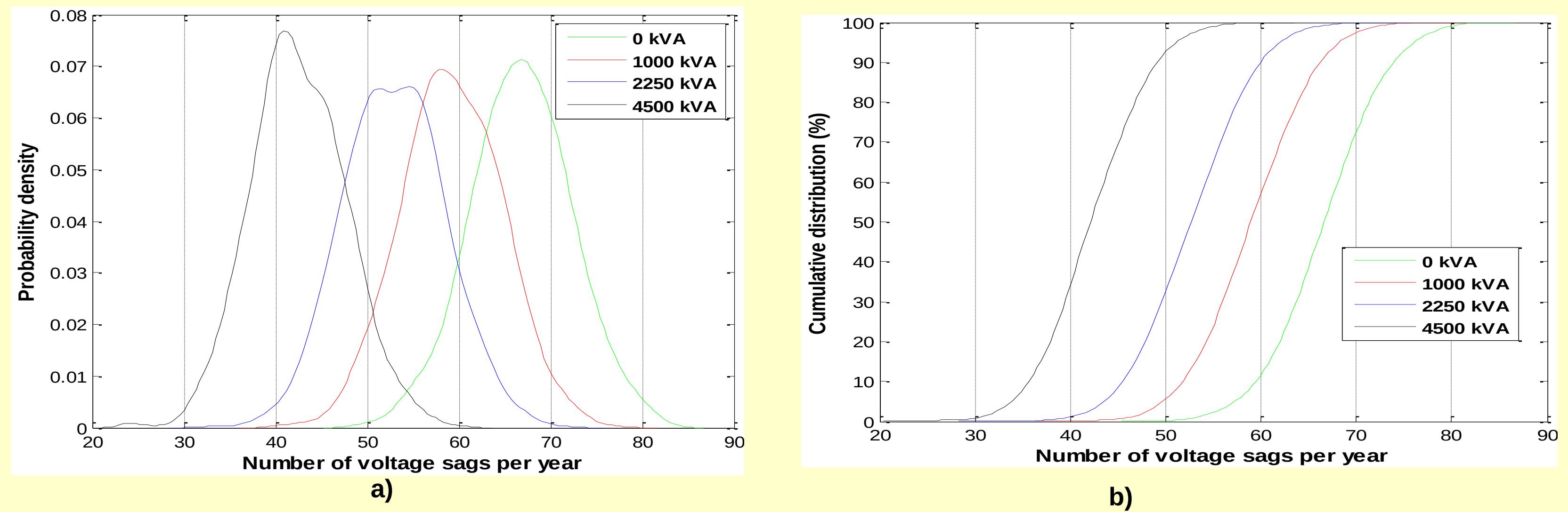

Fig. 3. Probability density (a) and cumulative distribution (b) of voltage sags at 9112 busbar for 0-4500 kVA.

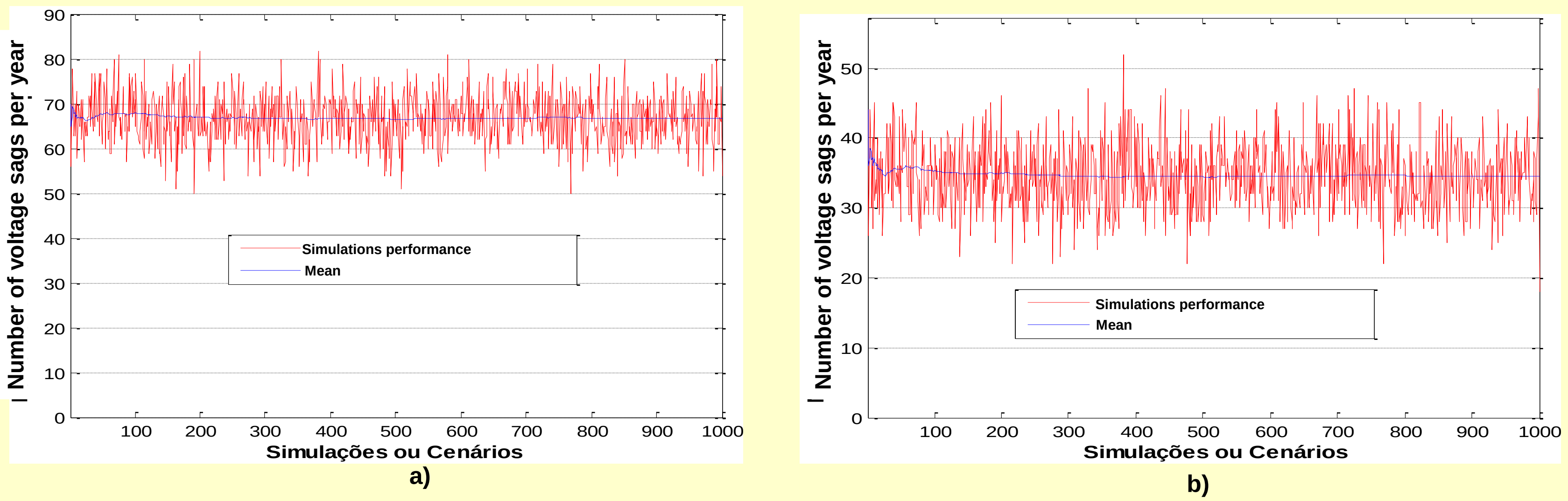

Fig. 4. Simulation performance and average number of voltage sags at busbar 9112 a) for 0 Ohm ; b) for 15 Ohm.

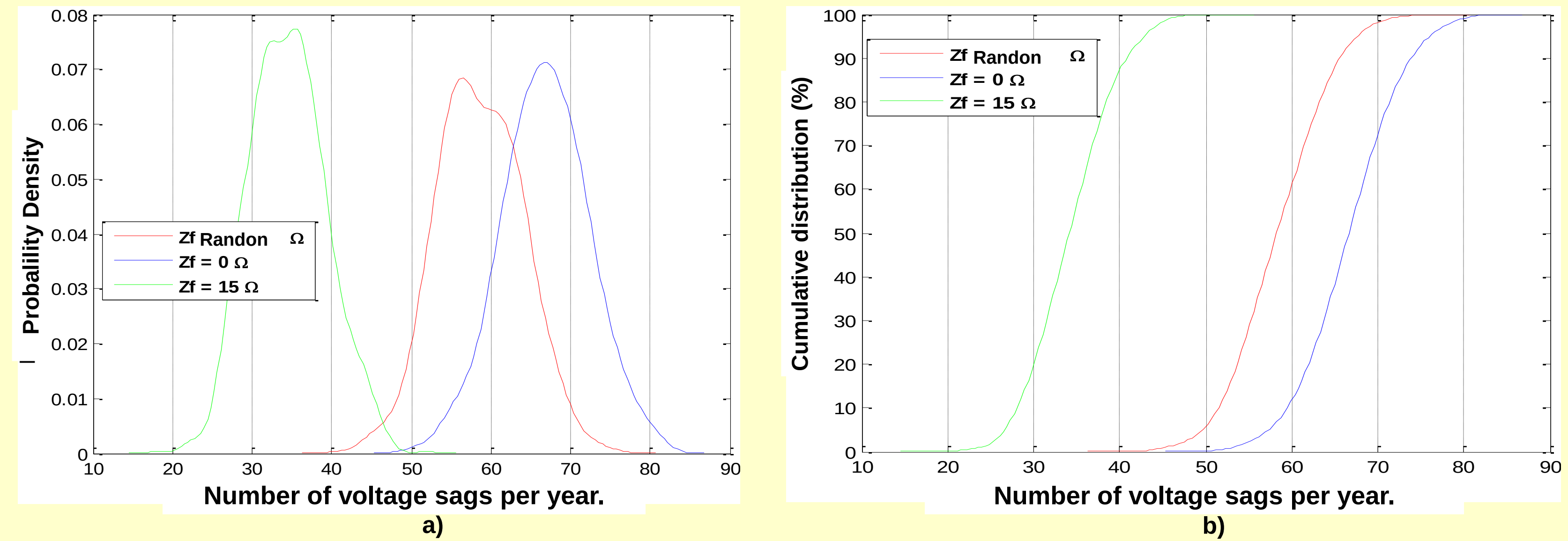

Fig. 5. Probability density (a) and cumulative distribution (b) of voltage sags at 9112 busbar for Zf = 0-15 Ohm.

3. Conclusion

The paper shows the impact of DG (Fig. 2-3) and Fault Impedance (Fig. 4-5) on voltage sag magnitude and frequency for a sensitive end-user. Voltage sags indices were obtained by the simulation of short-circuits. Long term simulation scenarios were obtained by the Monte Carlo method.
For each level of DG, the cumulative distribution function and the probability density curves for different classes of voltage sags were obtained. According to the results, the level of DG and network topology next to a sensitive end-user influences the total number of voltage sags and the number of voltage sags classified by classes of magnitude.
In general, it is shown that the greater the level of DG next to the end-user busbar, the smaller the number of voltage sags expected per year. Besides that, the most severe voltage sags become less frequent and the less severe voltage sags become more frequent with the increase of DG level (i.e., DG power rating).
In general, it is shown that the greater the Fault Impedance, the smaller the number of voltage sags expected per year. In general, the studies of voltage sags are more sensibles of fault Impedance than Distributed Generation.

References

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[3] Ramos, A. C. L.; Batista, A. J.; Domingues, E. G.; Calixto, W. P. A First Approach on the Fault Impedance Impact on Voltage Sags Studies, 2015. La Coruña, Spain, International Conference on Renewable Energies and Power Quality (ICREPQ’15).