Influence of Decentralized Generation and Network Configuration in the Harmonic Pollution of an Electric Power System

M. F. Coelho Monteiro (1) J. A. Dias Pinto (1) A. C. S. Machado e Moura (2)

(1) Departamento de Engenharia Electrotécnica
Instituto Superior de Engenharia de Coimbra
Rua Pedro Nunes, 3030-199 Coimbra, Portugal
fatcmont@isec.pt , jpinto@isec.pt

(2) Departamento de Engenharia Electrotécnica e de Computadores
Faculdade de Engenharia da Universidade do Porto
Rua Dr. Roberto Frias, 4000 porto, Portugal
mmoura@fe.up.pt

Abstract

Due to economical and environmental constraints decentralized generation plays a very important role in the electric power system production. This paper is devoted to the simulation of the influence of the decentralized generation in the harmonic pollution in a part of the Portuguese electric power system. The study was carried out using the commercial software package HARMONIQUE, developed by the Electricité de France (EDF). Linear load models and different operating points as well as decentralized generating units were considered. The generation levels were based on the available forecast. Changes in the network configuration were also taken into account. Finally, some conclusions that provide a valuable contribution to the better understanding of the effect of decentralized energy generation in the network are pointed out.

Keywords: Electric Power System, Decentralised Power Generation, Harmonics, Power Quality, Cogeneration

1. Introduction

In the last years due to the new governmental policy, the electric power generation based on cogeneration technology has been widely used. This technology combines heat or cold and power production to industrial processes or building climatization. These processes present important advantages such as a significant energy economy as well as the possibility of power factor compensation and less environment pollution [1].

A large number of power industries have already installed cogeneration production, but it is expected more similar plants due to the governmental goals. This results in a decentralized energy generation that provides several benefits to the production installation and to the electric power system.

The cogeneration units are distributed in the network avoiding the transmission costs, since they are close to the customers and also improve the efficiency of the industrial heat generation process [2]. These distributed plants associated with renewable energy sources may reduce power quality and produce important problems in the power network that should be analysed.

In this paper it is simulated and analysed the influence of the decentralized generation and of the network configuration in the harmonic pollution in a part of the Portuguese electric power system, considering the 150 kV and the 220 kV voltage levels of the transmission network. The simulation was performed using the software package HARMONIQUE. Linear load models and the generating scenarios for 2005 and 2007 were considered.

2. Applied Software

The study was carried out using the commercial frequency domain simulation software package HARMONIQUE, developed by the Electricité de France (EDF). The main feature of these efficient computer programs is to propose a unique solution to various issues with a high degree of performance. It uses detailed models that result from the work of CIGRE committee 36.05 that take into account all the harmonic sources as well as the current and voltage distortion in the power network [3].

3. Decentralized Generating Models

Induction or synchronous generators are usually used as decentralized power units. They can use constant or adjustable speed for the energy production. Most of the power units in wind farms as well as hydro plants and the gas turbines units are usually associated with adjustable speed electronic converter devices.

Constant speed generators do not include power electronics unless they have a special starting system, but adjustable speed generators have an on-line power converter.

Usually constant speed generators can alter the ripple control signals, but have no significant consequence on harmonic levels. Adjustable speed generators can lead to both damp ripple control signals and increase harmonic levels [4].

In the used models it was modelled the constant speed generators as an asynchronous machine and it was considered the inrush current and the power-factor compensation using a capacitor bank. For ripple control and harmonic studies, capacitor banks are particularly important.

In the used models it was considered the adjustable speed generators as an asynchronous machine and an AC/AC electronic converter. The speed can continuously vary from almost 0 to the nominal speed. In this situation it is used a power converter to adapt the frequency on both sides. The technology used for the AC/AC converter was based on thyristors.

4. Application Example

Figure 1 shows a simplified single line diagram of one part of the Portuguese transmission system. Only the 150 kV and the 220 kV voltage levels were considered. The simulation was carried out considering the decentralized generating power units connected to the 15 kV and 30 kV busbars. In the graphic scheme 16 overhead transmission lines, 13 busbars and 7 transformers were represented. In the diagram 5 large hydro and thermal power plants are shown. Due to the characteristics of decentralize generating units, they were not represented in this figure.

In this situation only the decentralised power units are harmonic sources that produce voltages and current distortion in the network.

The study was carried out assuming linear loads and two generating scenarios based in the 2005 and 2007 forecasts. For these scenarios it was simulated different network configurations, resulting in different contingencies.

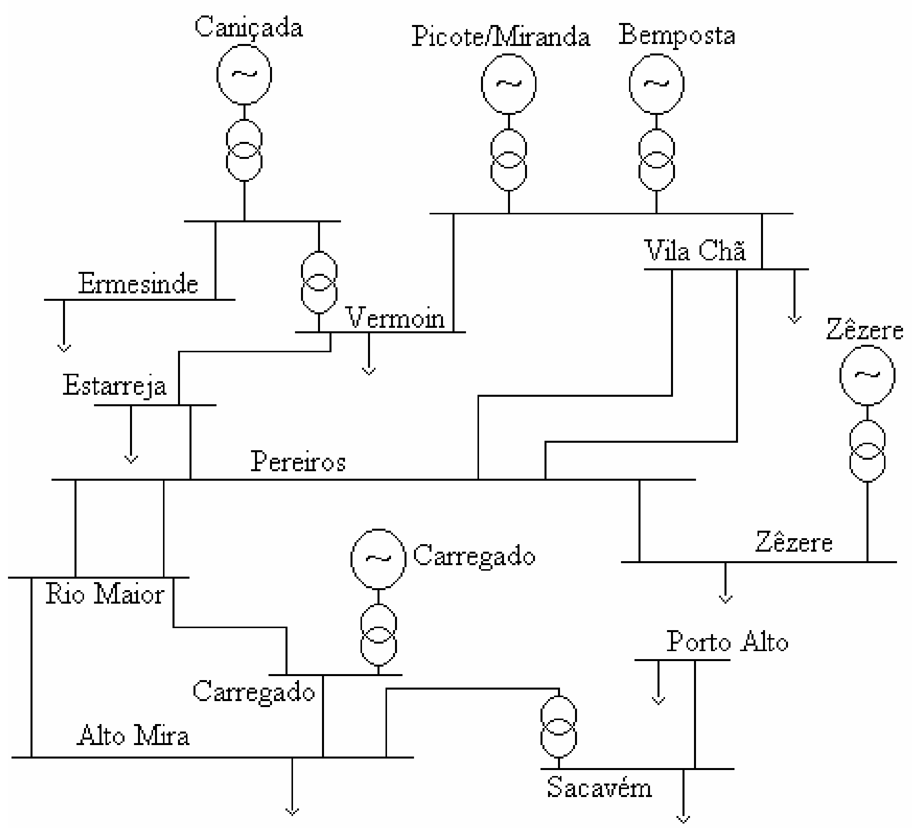

Figure 1: Test power network single line diagram

5. Results

Figures 2 and 3 present the harmonic voltages for 8 relevant network busbars for the forecast decentralize generating levels of 2005 and 2007 (Table 1) respectively. It was assumed that the decentralize power units are adjustable speed induction generators.

Table 1: forecast decentralized generating levels of 2005 and 2007.

busbar	2005	2007
Ermesinde	-	0.70
Vermoim	0.20	0.20
Estarreja	0.47	0.47
Vila Chã	0.31	0.50
Pereiros	-	0.50
Carregado	1.20	1.20
Alto Mira	1.70	2.98
Sacavém	1.00	1.96
Porto Alto	-	0.31

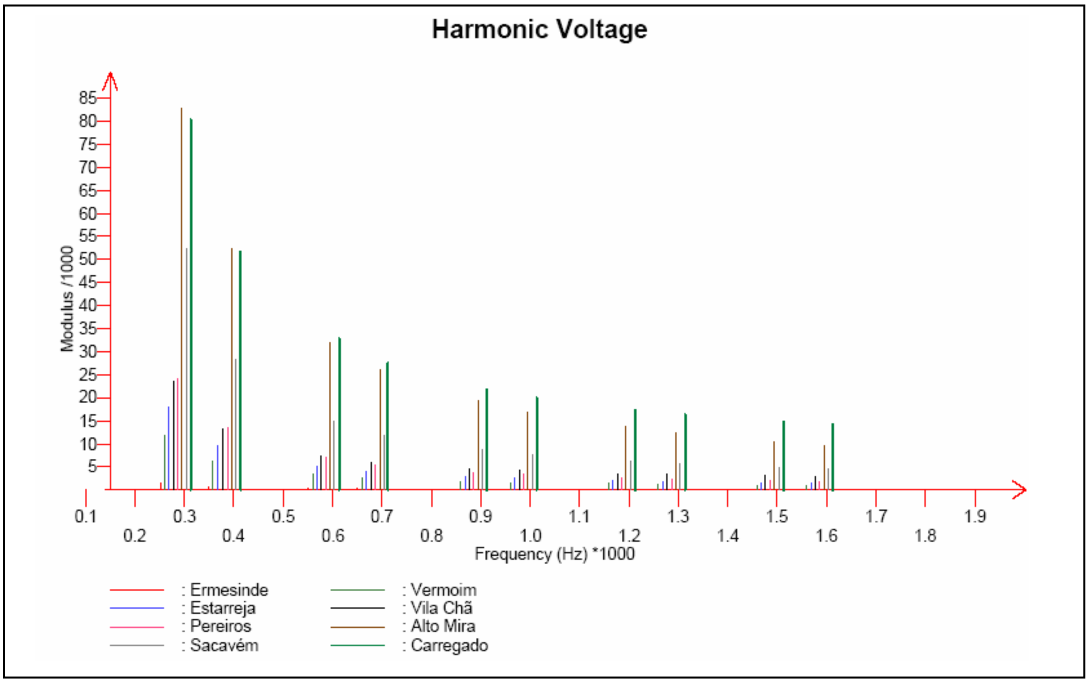

Fig. 2: Harmonic voltages for the 2005 forecast.

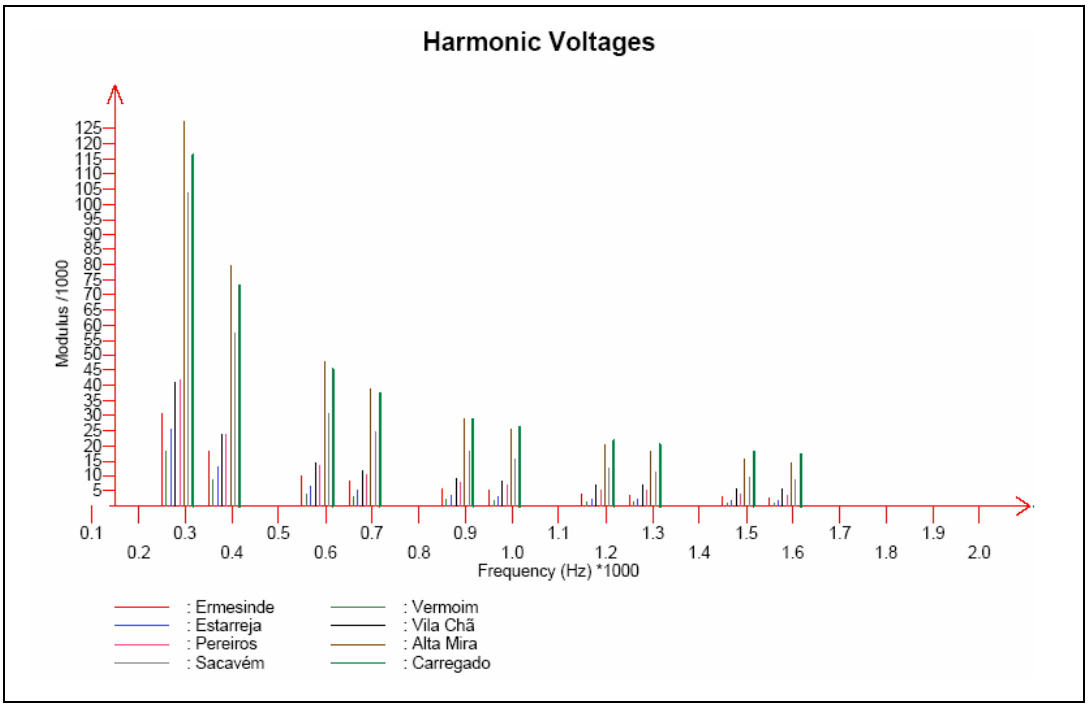

Fig. 3: Harmonic voltages for the 2007 forecast.

Figures 4, 5 and 6 show the harmonic impedances related to the 2007 forecast decentralized power generation (Ermesinde, Vermoim, Estarreja, Vila Chã, Pereiros, Alto Mira, Sacavém and Carregado busbars).

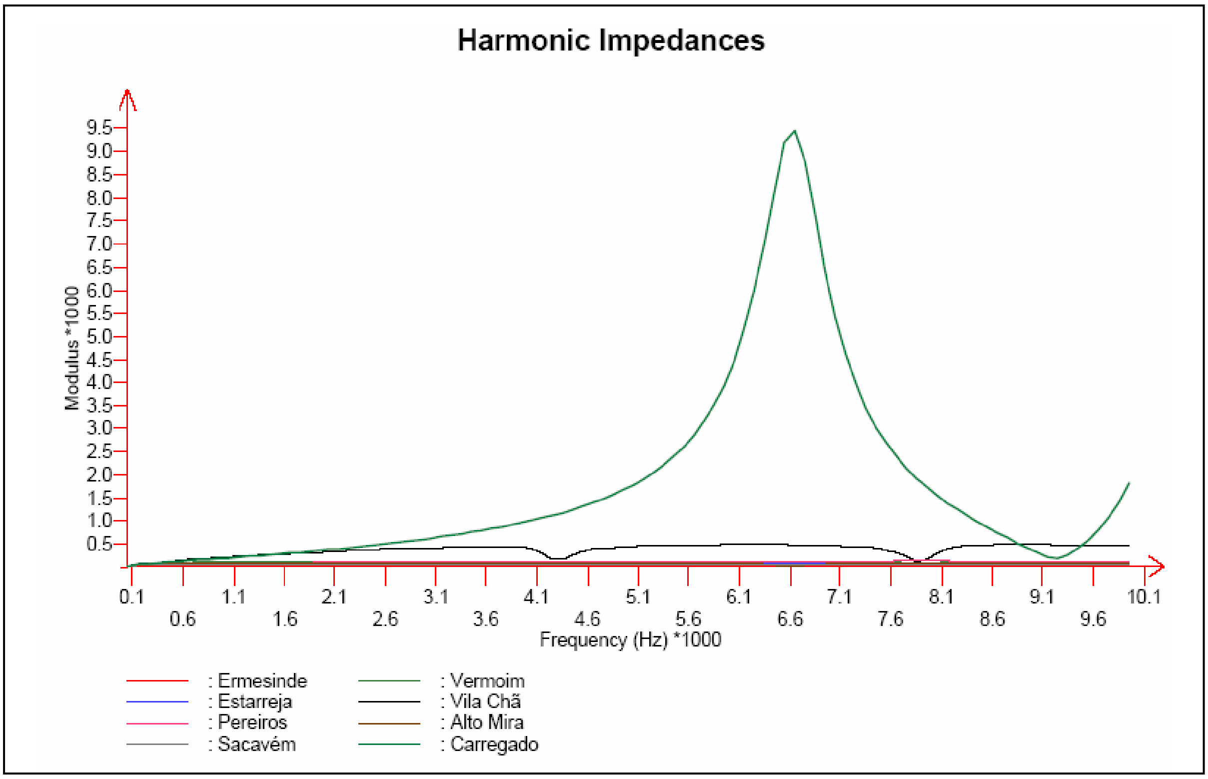

Fig. 4: Harmonic impedances for the 2007 forecast decentralized power generation, related to the Carregado and Vila Chã busbars.

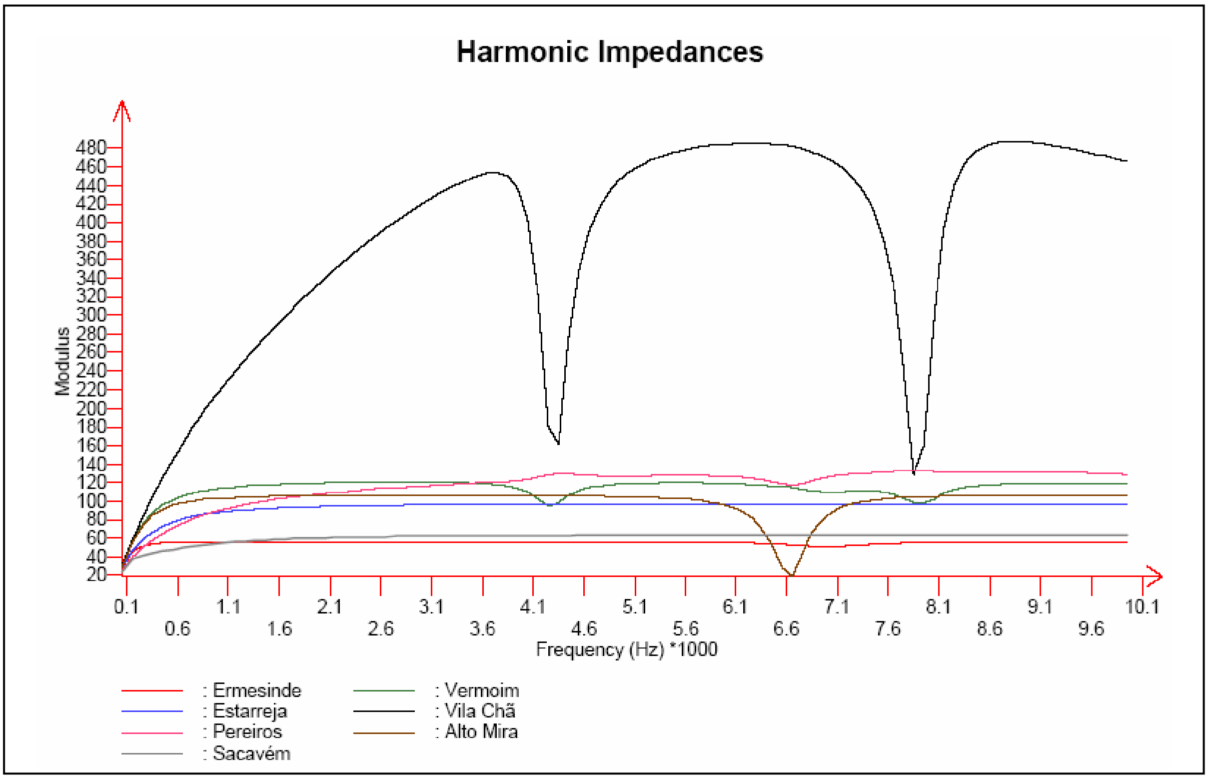

Fig. 5: Harmonic impedances for the 2007 forecast decentralized power generation, related to the aforesaid busbars.

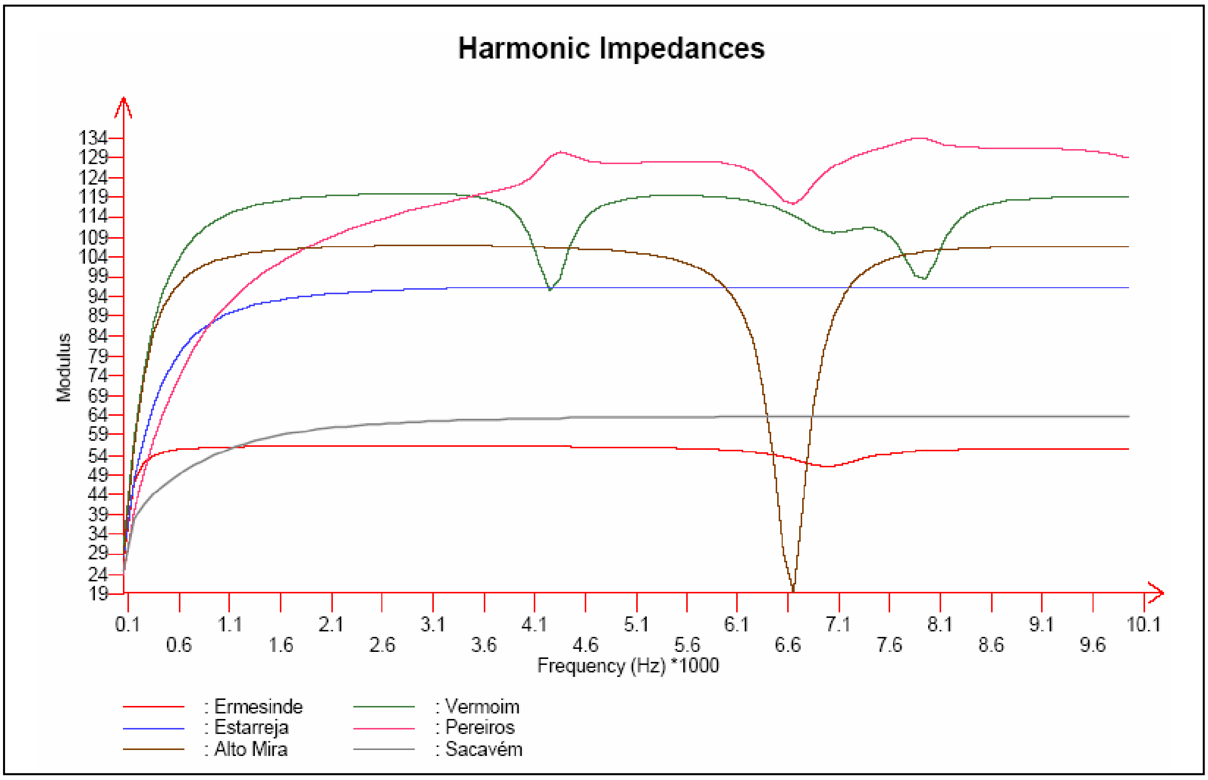

Fig. 6: Harmonic impedances for the 2007 forecast decentralize power generation related to the Ermesinde, Vermoim, Estarreja, Pereiros, Alto Mira and Sacavém busbars.

Due to the large number of results, it is only shown the results for some simulations. In the first case the transmission line L3 is considered out of service.

Figure 7 presents the harmonic voltages for this scenario considering the 2007 forecast decentralized power generation.

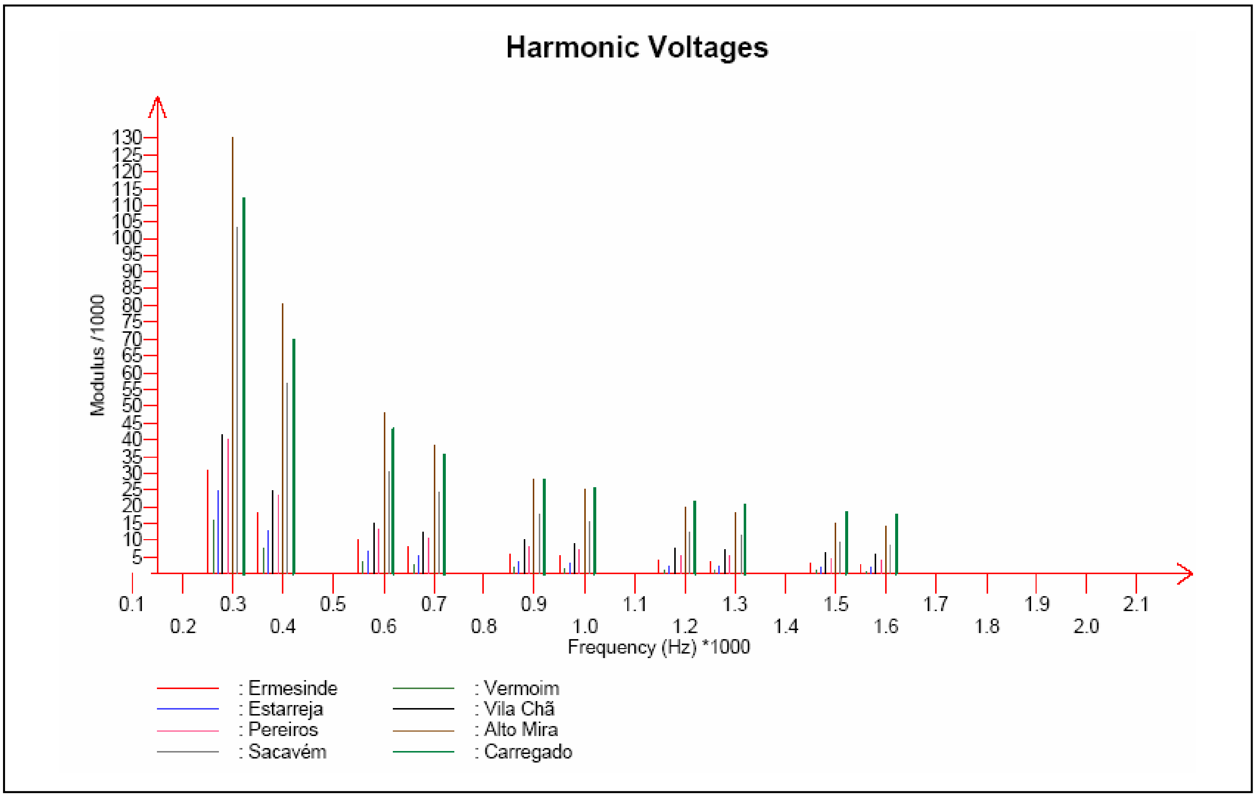

Fig. 7: Harmonic voltages for the 2007 forecast with L3 out of service.

Figures 7, 8 and 9 show the harmonic impedances refereed to the 2007 forecast decentralized power generation, considering transmission line L3 out of service.

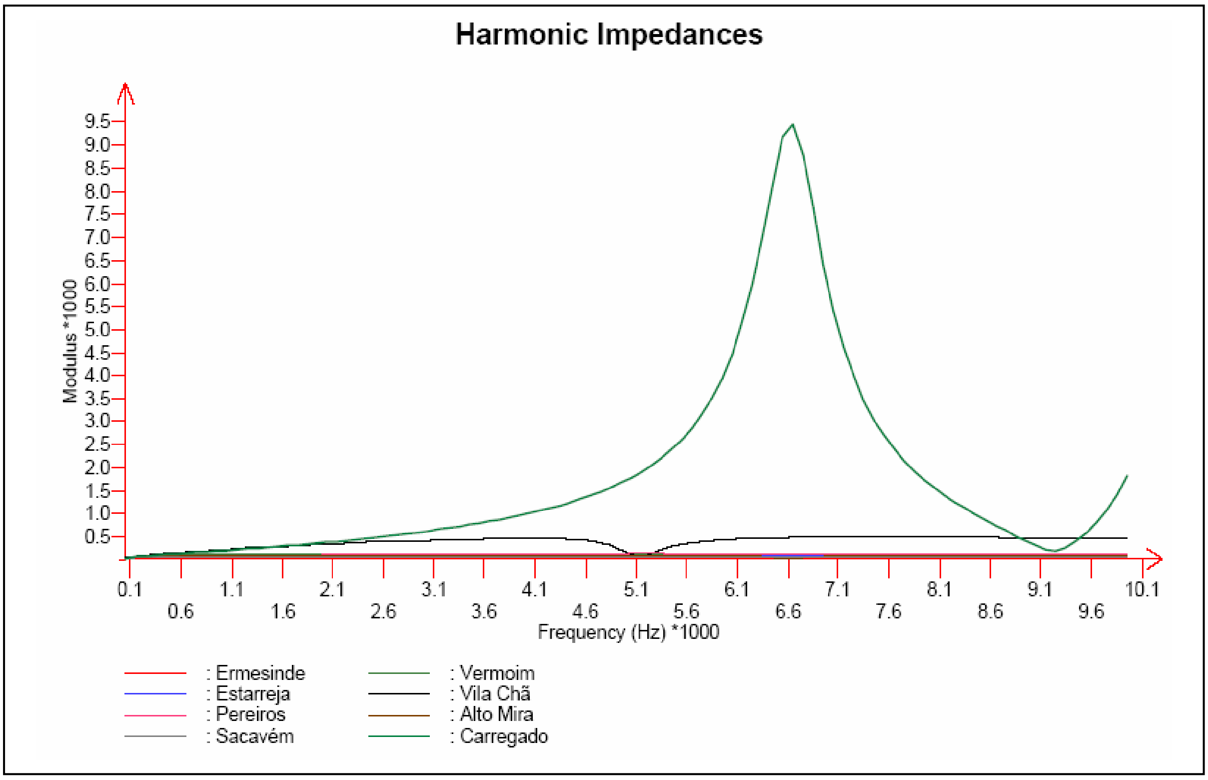

Fig. 7: Harmonic impedances for the 2007 forecast decentralized power generation related to the Carregado and Vila Chã busbars, with L3 out of service.

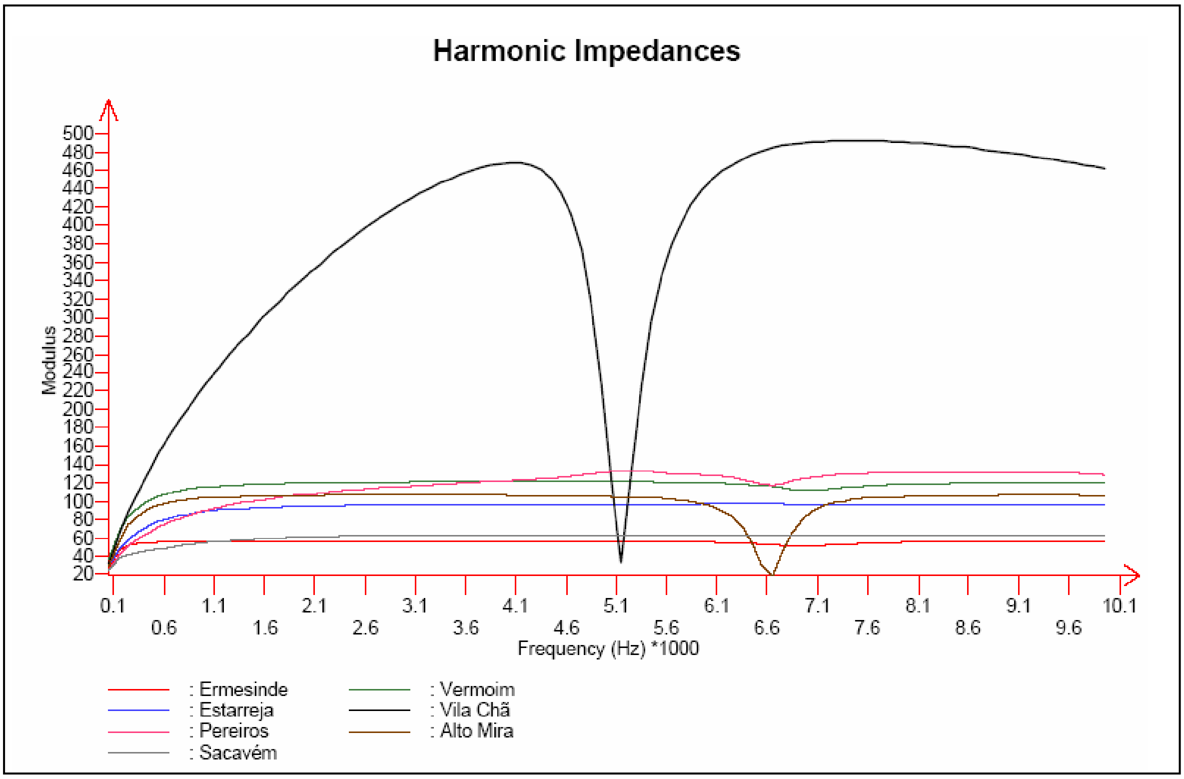

Fig. 8: Harmonic impedances for the 2007 forecast decentralized power generation related to the refereed busbars, with L3 out of service.

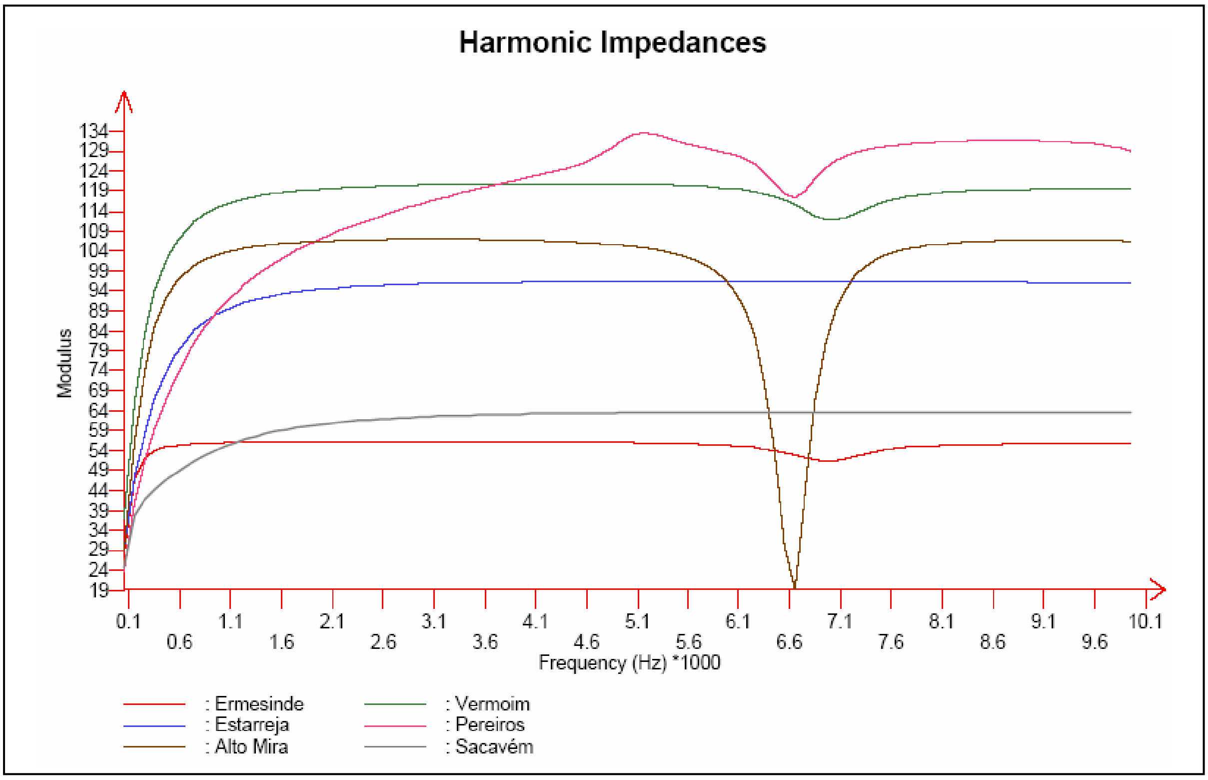

Fig. 9: Harmonic impedances for the 2007 forecast decentralize power generation related to the Ermesinde, Vermoim, Estarreja, Pereiros, Alto Mira and Sacavém busbars, with L3 out of service.

Figure 10 shows the harmonic voltages refereed to the 2007 forecast decentralized power generation, considering transmissions lines L3, L2 and L17 out of service.

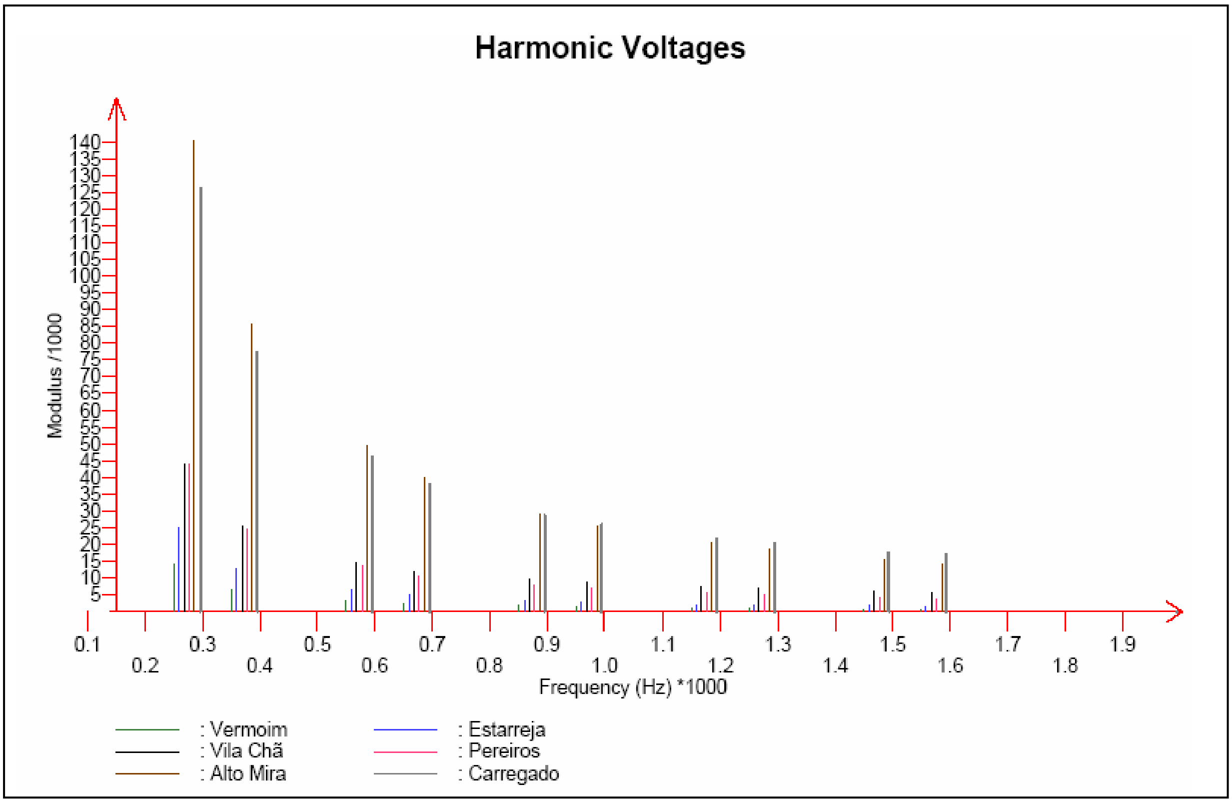

Fig. 7: Harmonic voltages for the 2007 forecast with L3 out of service.

6. CONCLUSIONS

It was studied and analysed the influence of the decentralized generation in the harmonic pollution in a part of the Portuguese transmission power system, considering only the 220 kV and the 150 kV levels. It was used the commercial software package HARMONIQUE developed by EDF. From the above results the following relevant conclusions can be extracted:

- For all the analysed scenarios only the 5, 7, 11, 13, 17 and 19 harmonic voltages are generated;

- For all the situations that were simulated the most relevant distortion corresponds to the 5^{th} harmonic voltage;

- The Alto Mira busbar presents the most harmonic distortion for the all the considered scenarios;

- The Ermesinde busbar presents the lowest harmonic distortion for all the considered scenarios;

- For the 2007 forecast decentralized generation, an increase in the harmonic distortion arises for all network busbars;

- Considering the 2007 forecast decentralized generation, a serial resonance phenomenon arises for all busbars, namely for Vila Chã it occurs at 4.3 kHz and at 7.9 kHz, and for Alto Mira busbar it occur for 6.6 kHz;

- Considering the 2007 forecast decentralized generation, the Carregado busbar presents harmonic impedances values greater than the other network busbars, and occurs a parallel resonance phenomenon at 6.6 kHz

- Considering the 2007 forecast decentralized generation, and the transmission line L3 out of service, occurs a significant increase in the harmonic voltages values for the Ermesinde, Alto Mira and Carregado busbars;

- Considering the 2007 forecast decentralized generation, and the transmission line L3 out of service, a significant change occurs in resonance phenomenon in the harmonic impedances values for the Vila Chã, and Vermoim busbars;

- Considering the 2007 forecast decentralized generation, and the transmission lines L3, L2 and L17 out of service, a significant increase occurs in the harmonic voltages values for the Vila Chã, Vermoim, Alto Mira and Carregado busbars;

Harmonic studies play a very important role during the design, planning and operation stages of the electric power system in order to minimise voltage and current distortions produced mainly by decentralized power generation and consequently to improve its power quality level.

7. References

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