Harmonic distortion evaluation using the Wind Turbine harmonic voltages sources method instead of simplified ideal harmonic current sources method

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ABSTRACT

The modern wind turbines (WT), equipped with power converters (full or partial power converters) connected to the grid, have increased rapidly in recent years. Harmonic assessment of the power quality is a necessary study for interconnection of future wind farms to the grid. Normally, the power quality assessment in wind farm is done considering the power converter as an ideal harmonic current source, then, the injected harmonic currents are considered constant in any grid. This approach is not always valid since it neglects any grid harmonic impedance impact as well as the converter reaction to background harmonic voltages.

In this study it has been modelled the Alstom Haliade 150 6MW wind turbine converter as a harmonic voltage source, including its filter and transformer harmonic model; with the theoretical harmonic impedance model and the background harmonic voltages of Le Carnet Wind farm (France) . The predicted voltage and current harmonics have been compared with real data measurement. The accuracy of this evaluation is much closer to reality than considering converters as ideal current sources as usual.

Keywords: *Grid Integration, wind turbine, power quality, harmonic distortions, full power converters, DFIG converters*

1. INTRODUCTION

A standard approach about a theoretical wind farm power quality assessments are done considering each WT as an ideal harmonic current source [1]. In this case, the different harmonics currents are often taken during the WT prototype power quality certification [2] and these are measured in a particular site with a particular grid. This grid could be completely different than the future grids where this sort of WT will be installed; even this specific grid harmonic impedance could have some serial or parallel resonances in some particular frequencies [3]. Thereby, the Power Quality assessment of a particular site only shows the injected harmonic currents of this specific site. If the ideal injected harmonic currents are used in other sites, it is neglected their dependency with the harmonic grid impedance and the converter reaction to background harmonic voltages. Hence, the estimation of harmonic distortions obtained with this approach might deviate of the real harmonic distortion.

The intention on this proposal is using the real voltage source of harmonics and the grid characteristics (harmonic impedance and background voltage harmonics). So, from one side the converter inner harmonic voltages, the ones generated by the IGBT bridge which are almost constant and quasi-independent of the grid, and secondly face them against the grid model taken from the DSO (Distribution Systems Operators) data.

It is shown the results of a site evaluation example in Alstom Haliade150 WT prototype site (Le Carnet, France), where is demonstrated a good accuracy of this methodology to make a power quality assessment using the converter voltage harmonics and the grid model (harmonic impedance and background voltage harmonics).

Despite the current study only deals with WTs with full power converter, so all the harmonics face to the grid are generated by the line side of the power converter. In any case, this methodology might be easily extended to DFIG topology, where voltage harmonics generated by the machine side of the power converter which are transferred to the grid also by the rotor/stator winding generator.

2. EVALUATION PROCESS

The converter and grid harmonic currents are calculated separately in this methodology. A first model includes the harmonic impedances of the wind turbine and the grid; with the voltage harmonic source belongs to power converter side in order to get the current harmonics really caused by the converter. A second model includes the harmonic impedances of the wind turbine and the grid as well, but with the background voltage harmonics in order to get the current harmonics caused by the converter reaction to background voltage harmonics.

2.1. Voltage harmonics.

As the case analyzed deals with a full power converter, the only sources of harmonics at the wind turbine level are coming from the Line Side Converter on the IGBT output and the voltage harmonics coming from the grid as background harmonics before connecting any WF.

The voltage harmonics from the converter have been measured directly on the IGBT side of the line side converter (Fig. 1), and the background voltage harmonics coming from the grid have been measured on the MV of the transformer having the WT disconnected (Fig. 2).

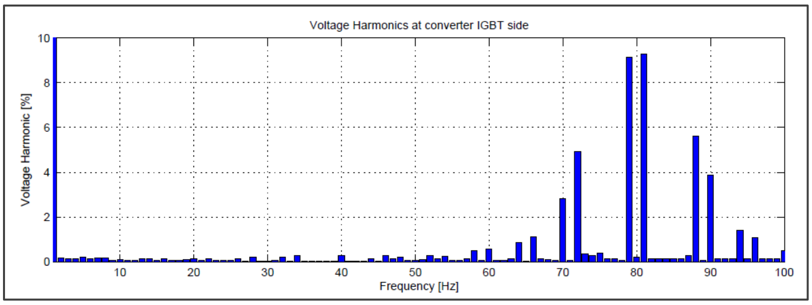

Figure 1- Voltage harmonics at converter IGBT side (WT source)

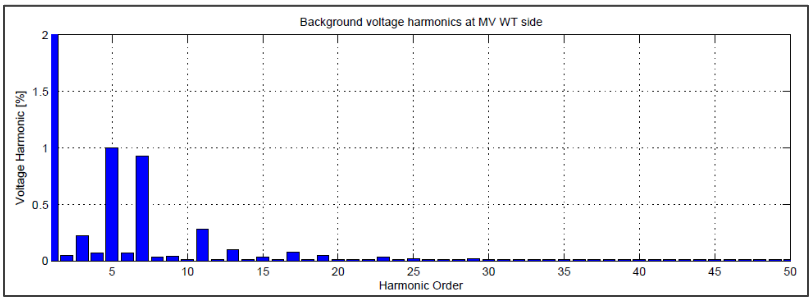

Figure 2 – Background voltage harmonics at MV WT side (Grid Source)

2.2. System model

The system has modeled using the wind turbine data (filters + transformer) and the grid data from the DSO [4] to calculate the different sections (each section modelled in “PI” models) as it is depicted in figure 3.

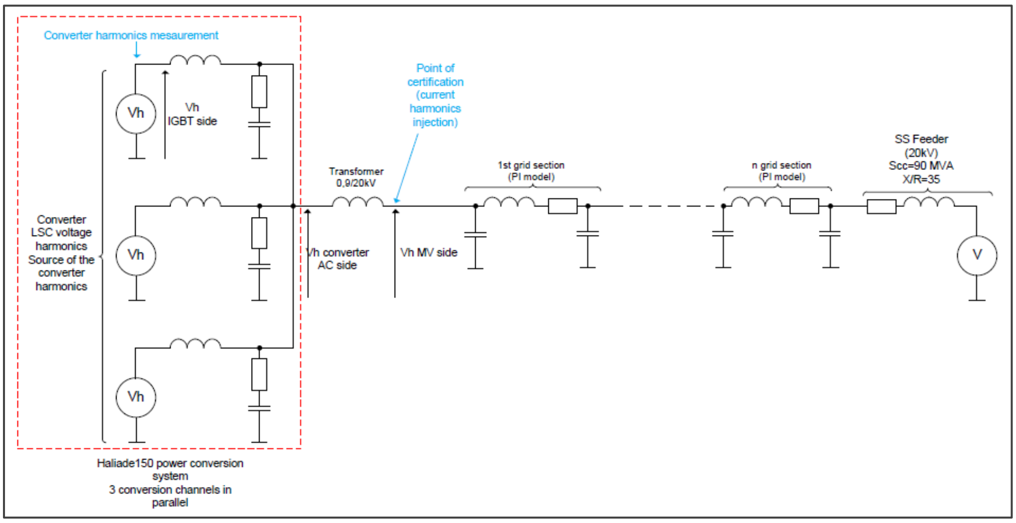

Figure 3 – Converter, cables and grid model

The grid model MV impedance has been collated with the Z_h obtained by a direct V_h/I_h measurements and both $Z_h(f)$ are so similar, so the theoretical grid model provided by DSO (Fig. 4) is quite valid for being used for the voltage distortion assessment.

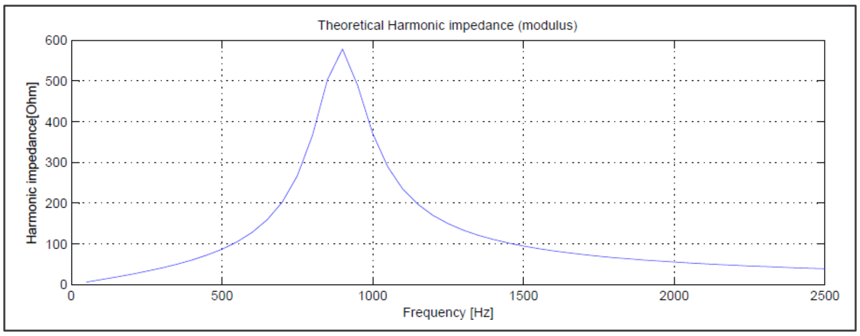

Figure 4- Theoretical harmonic impedance

2.3. Voltage and Current harmonics Calculation

The voltage and current harmonics have been obtained with the method of Modified Nodal Analysis (MNA) [5] which is an extension of classical Nodal Analysis [6], per each harmonic. The procedure is depicted in Figure 5.

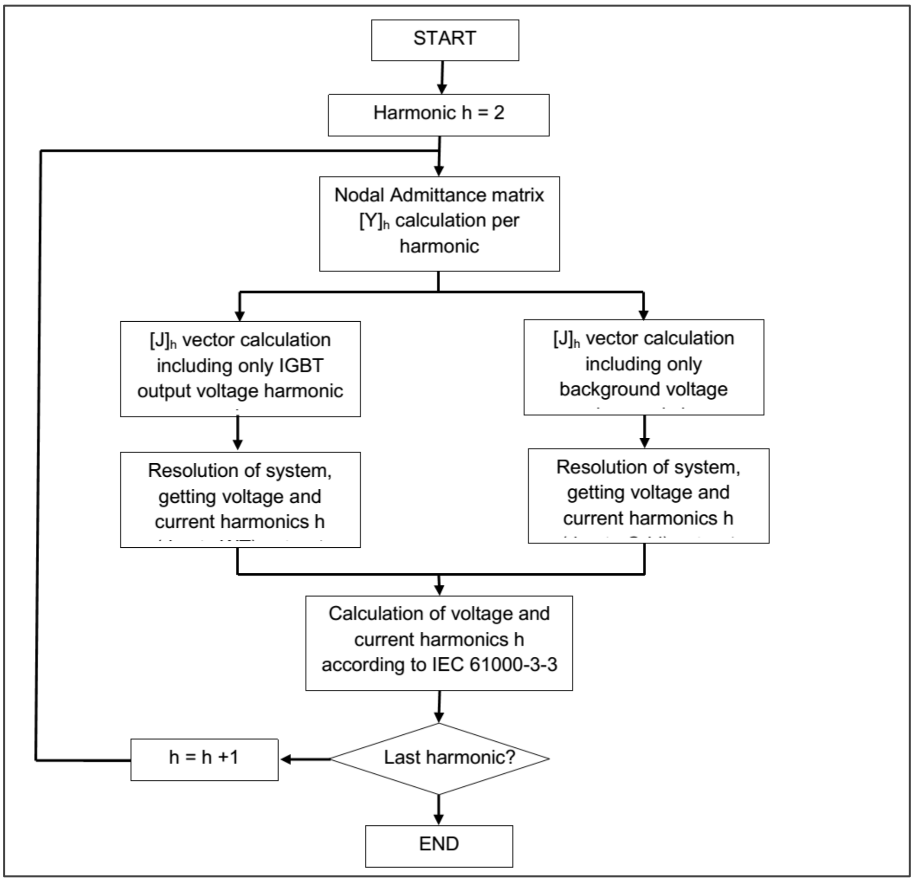

Figure 5- Voltage and current harmonics calculation procedure

Converter and grid harmonic currents are calculated separately. the 1st simulation for calculating only the impact of the power converter harmonics (Fig. 6) and having then the background grid harmonics off, i.e. voltage source shortcircuited; and the 2nd simulation for getting only the converter reaction to the background voltage harmonics coming from the grid (Fig. 7) and having then the power converter source shortcircuited.

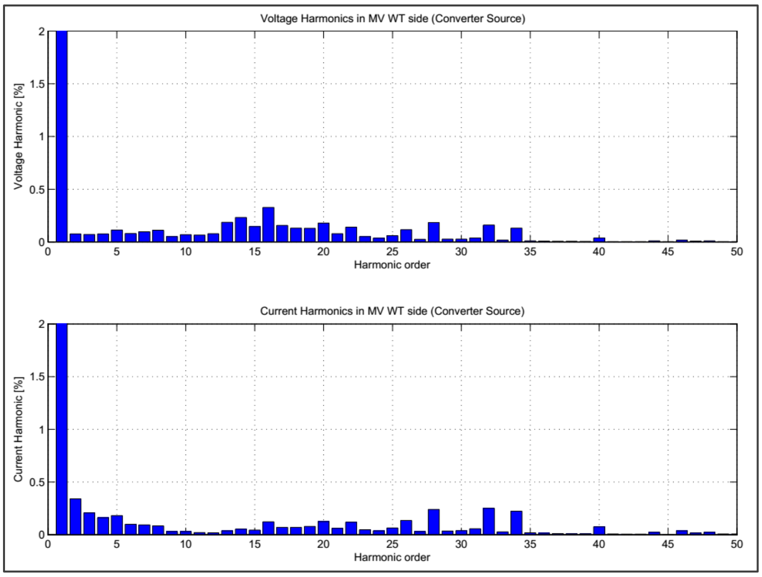

Figure 6- Voltage and current harmonics in the MV WT side (converter source)

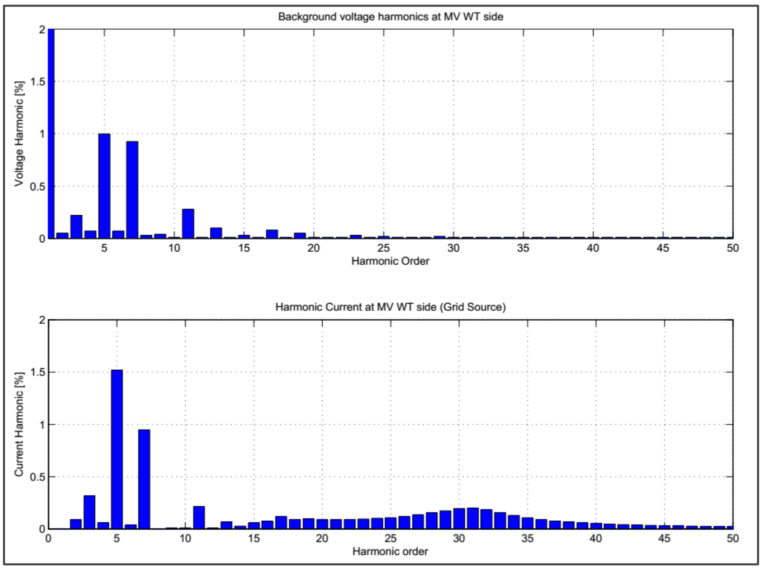

Figure 7- Voltage and current harmonics in the MV WT side (Grid source)

The two terms (current and voltage harmonics) have been summed using the summation rule proposed in the IEC 61000-3-3 [7]. From simulations results we can obtain the current harmonics on the MV, the harmonic impedance (impedance vs freq.), and the voltage distortion in any point of the grid model (Fig. 8).

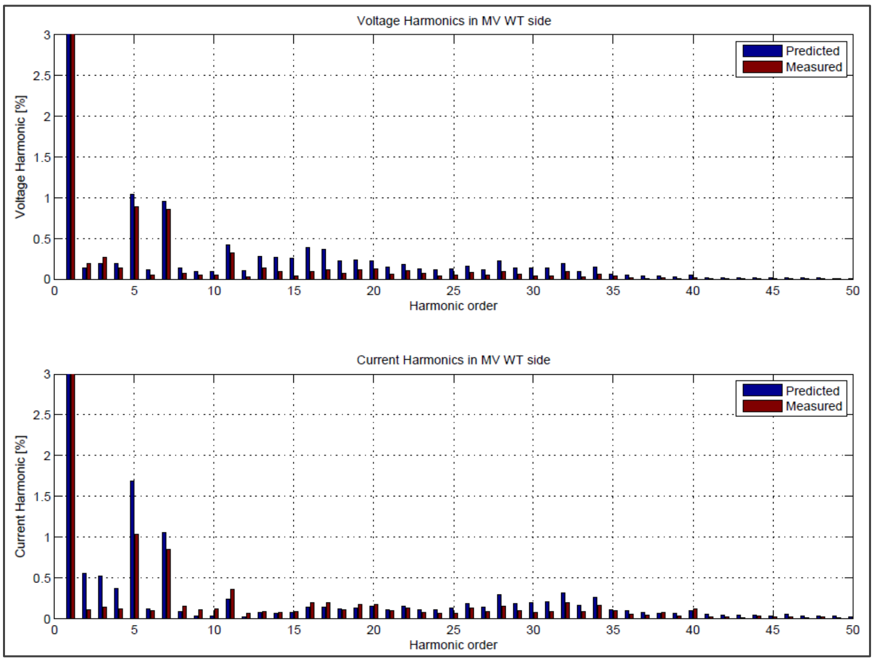

Figure 8- Voltage and current harmonics in the MV WT side

3. CONCLUSIONS

The estimation of the voltage and current distortion on the WF PCC is more realistic by using the voltage harmonics source method coming from the power converter and the grid harmonics background than only forcing an injection of current harmonics which are coming from measurements done in a particular site (WT prototype certification).

The theoretical Z_h(h) get with the DSO data (“PI” modelled sections + transformers) has the same trend to the real $Z_h=V_h/I_h$ get by direct measurements on the MV side. It means the grid could be simulated quite accurately without the real voltage and current harmonics previously measured on the site.

The voltage and current harmonics in the lower range, so the 3^{rd} , 5^{th}, 7^{th}, 11^{th},…, which are normally detected in all the WT power quality assessment are normally coming from the background harmonics already existing in the grid and the power converter has nothing to do with them.

The power converter is usually responsible from the harmonics around the switching frequency and all its multiples.

4. REFERENCES

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5. BIOGRAPHIES

Oriol Caubet-Busquet (Barcelona, May 1975) received the MsC Industrial Electronics & Automation from Catalonian Polytechnic University, Terrassa, Spain in 2003.

He has been working in the wind industry for the last 8 years. He is currently a senior electrical engineer working in the Alstom Wind R&D Energy conversion group in the headquarters office of Barcelona. Before working in the wind industry, he has worked in several companies (test equipment, servo control and train equipment) always involved in automation and mechatronics devices for 9 years. Since 2007 fully involved in the application design of the wind turbines power converters, first for the DFIG machines and the last 5 years dedicated on the full power ones.

Mr. Caubet. His main interests are grid integration of wind turbines and the design of power converters for wind applications.

Sergi Ratés-Palau (Barcelona, September 1968) received the Engineering degree and the Ph.D degree in electrical engineering from Catalonia Polytechnic University, Barcelona, Spain, in 1992 and 2012 respectively.

He has worked in the field of electrical engineering for more than 20 years, including more than 12 years for energy conversion systems in wind applications. Since 2011, he has the Technical Leader of energy conversion system in R&D department for Alstom Renewable Power.

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