Harmonic emission of wind power plants: measurement and assessment

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1. Introduction

Harmonics have always been a topic of special concern when planning and designing a power system. However, now that the number of renewable energy sources such as wind turbines is only increasing by the day, it is of special interest to study in depth this topic, due to the possible failure or damage of sensitive elements that could occur when the distortion of a current or voltage waveform surpasses some limits.

There are measurement and assessment standards such as IEC 61400-21 [1] which provides the procedure to measure and assess the harmonic current emission of wind turbines connected to the grid and IEC standard 61000-4-30 [2] that specifies the methodology to measure harmonic emissions in power systems. Besides studying voltage and current harmonic emissions from wind turbines, an assessment of harmonic impedance is necessary during harmonic filters design or in those situations where it is necessary to evaluate the power quality of the energy provided by the wind turbine. The knowledge of the harmonic impedance spectra could be useful for the assessment of the risk of failure caused by load overloading or systems resonances. Harmonic impedance spectra could be used to decide whether the connection of a new wind turbine could cause any problem into the power system or not [3].

In order to quantify the harmonic impedance, a proper evaluation of the voltage and current harmonic components due to the wind turbine at the point of common coupling is needed. In this paper the harmonic impedance analysis from existing wind power plants and its influence on the power systems are studied in order to evaluate if the harmonic emission from a wind power plant could cause any failure or resonance problem in the power systems.

2. Approach

In order to achieve the main objective of this paper, the measurements of current and voltage on a wind turbine were obtained using a power quality analyser based on National Instruments equipment. This equipment performs the power quality evaluation complying with procedures described in the IEC standard 61400-21 [1].

The current and voltage waveforms were acquired complying with the standard IEC 61400-21 that recommends a 10-cycle window for power systems with a fundamental frequency of 50 Hz. The sampling rate recommended by the IEC 61400-21 as a minimum is 20 kHz that leads to a resolution of 400 points per cycle. In order to reduce spectral leakage, harmonic and interharmonic groups and subgroups are obtained as recommended in IEC standard 61000-4-7 [4].

The aim of this paper is to perform the evaluation and analysis of harmonic impedance in the medium voltage side of a single wind turbine using non-invasive techniques. The methodology proposed to achieve this is the evaluation of voltage and current harmonic measurements at the point of common coupling as is has been done in [5]. The number of publications regarding non-invasive experiments is relatively small [3].

3. Results obtained

Standard IEC 61400-21 [1] states that during the measurement acquisition, data should be sorted in active power bins for different power production levels:10, 20, … , 100 % of nominal power (P_n) of the wind turbine; consequently 11 active power bins are obtained.

In order to quantify harmonic impedance, current and voltage harmonic measurements from the medium voltage side of the wind turbine transformer were used. Then, for each active power bin and harmonic order, harmonic impedance is obtained as:

$$G_{sg,n,Z} = \frac{G_{sg,n,V}}{G_{sg,n,I}}$$

where $G_{sg,n,V}$ and $G_{sg,n,I}$ are the voltage and current harmonic subgroups derived from the DFT following IEC standard 61000-4-7 recommendations; and $G_{sg,n,Z}$ is the harmonic impedance.

Fig. 1 shows the harmonic impedance calculated for power production levels 0, 20, 40, 60, 80, 100 % of P_n (active power bins 0, 2, 4, 6, 8 and 10).

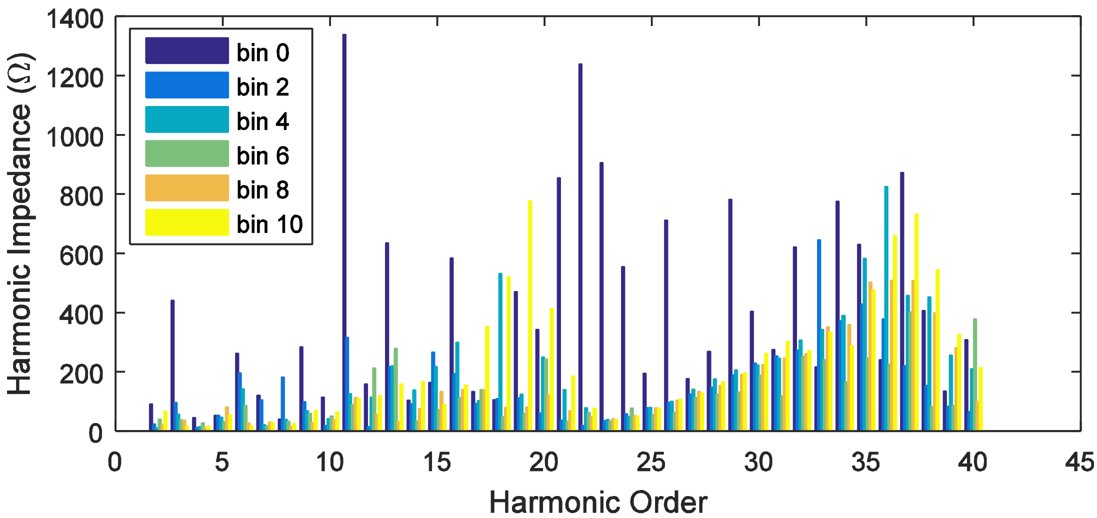

Fig. 1 Harmonic impedance for different active power bins

Important information can be drawn from the results. The impedance obtained from low power production measurements (i.e. bin 0) is considerably higher at lower harmonic orders (i.e. lower frequencies) compared to other active power bins, reaching its greatest value at harmonic order 11. On the other hand, impedance calculated from measurements obtained at nominal power (i.e. bin 10) seems to be lower at the 2-15 harmonic order range to then increase towards its highest value at harmonic order 19; then it decreases to a minimum at the 23rd order to, again, escalate to a local maximum at harmonic order 37.

4. Conclusion

Evaluation of harmonic impedance in the medium voltage side of several wind turbines will be presented in the paper where the analysis will be cover the whole generation range (0%-100%Pn). Non-invasive methodology is used in order to obtain information that will help to evaluate the quality and state of the power system, and to assess the risk of failure due to overload and resonance in the grid.

5. Learning objectives

The main goal of this paper is to analyse and evaluate the harmonic impedance at the point of connection of a wind turbine generator. This information and knowledge can then be used by designers, manufacturers, developers, TSO's, etc. to understand and solve the contribution to the harmonic emission at the PCC from utilities and customers [6].

References

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