

Harmonic current emission of wind farms exceeding the limiting values

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Summary:

Calculations within the new certification procedure in Germany since beginning of 2010 showed, that harmonic current emission in most existing and planned wind farms are exceeding the limiting values of the grid codes, although no distortions from the harmonic emission was recognized by the grid operators. This presentation will show the background and will give an overview of the work of a working group at the FGW and of the actual situation of the assessment of harmonic currents regarding grid connection and SDL WindV.

1 Introduction

During the certification procedure of the electrical characteristics of wind turbines it was recognized, that most of the installed wind farms but also of the planned wind farms in Germany exceed the limiting values of harmonic currents, when using the standard methods to calculate the harmonics of a wind farm from the harmonic current emission of a single wind turbine. From their own experiences the grid operators accepted this exceeding of the harmonic limits in the past, particularly as some measurements at wind farms have shown lower harmonic currents than the calculated ones, based on the standard methods. But with the new certification procedures for wind farms together with the new feed-in law (SDL WindV) /1/ this exceeding of harmonic current limits cannot be accepted. Until beginning of 2011 there is a temporary regulation in Germany, to fulfil the requirements of the SDL WindV /1/ also in such cases, where the limits of the harmonic currents are exceeded. But there is still an unclear situation for 2011, if the SDL WindV /1/ or the BDEW /2/ will not be adapted.

Within the committee of the FGW-guideline TR3 /3/ a new working group was established to find solutions for the harmonic current problems. Members of the new working group are from manufacturers of wind turbines and photovoltaic, grid operators, operators and planers of wind farms and photovoltaic, measurement Labs and universities. The author is the chairman of this working group.

2 The current procedure

The current procedure for assessment of harmonics in Germany is as follows and as illustrated in the figure 1. Measurements of harmonic current emission are performed at a single wind turbine according to IEC61400-21 /4/ and FGW TR3 /2/. From these measurements the harmonic current emission of the wind farm is calculated by multiplying with the square root of the number of wind turbines, compare figure 1. This geometrical summation law reflects the statistical behaviour of today's PWM (pulse width modulated) inverter systems, used in wind turbines.

At the other hand the limited values for a wind farm project at a specific site is calculated as follows and as illustrated in figure 2.

The grid code (for example the BDEW guideline) gives a table of limited values for each harmonic current up to 9 kHz. But these limited values are normalized to the short circuit power of the grid. Thus to calculate the real limited values at a specific site, these data of the table must be multiplied by the short circuit at the grid connection point of the specific wind farm project. But also other wind farms, connected to the same grid connection point or at the same substation must be taken into account. Thus only a portion of the total limited values can be used for a specific wind farm, as illustrated in the figure 2.

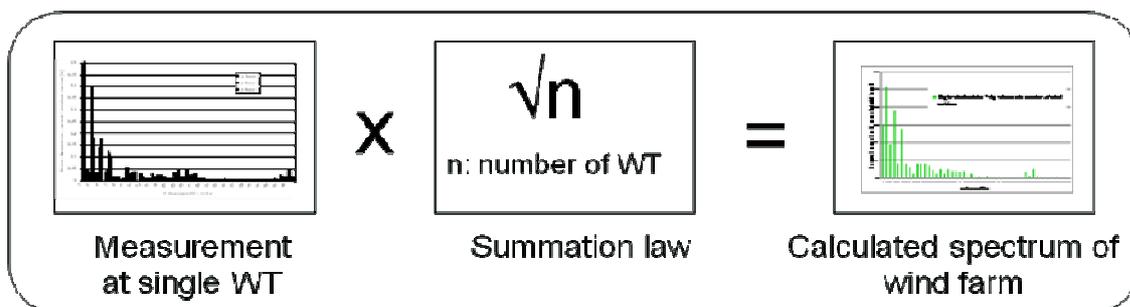


Figure 1: Procedure for the determination of harmonics of a wind farm.

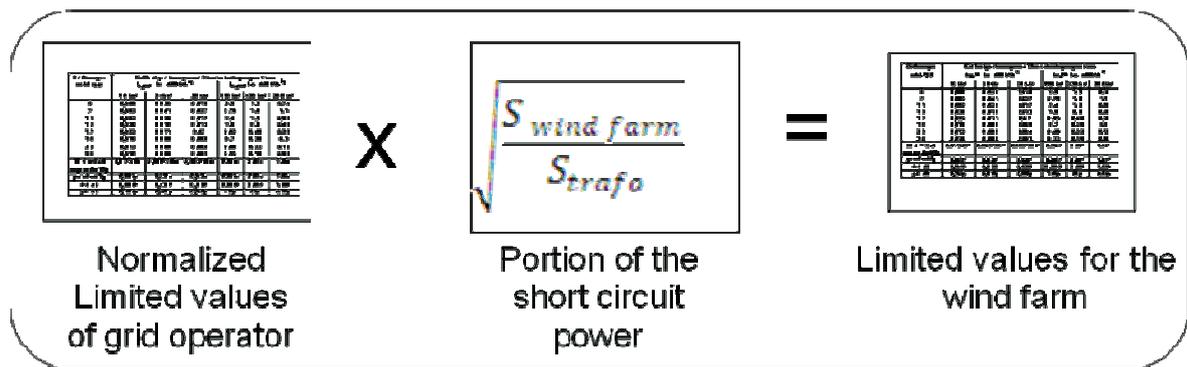


Figure 2: Procedure for the determination of the harmonic limited values of a wind farm at a specific site.

In often cases the calculated limited values are quite low, just for the higher frequency range or for interharmonic currents, where the limited values for the harmonic currents could be below 0.2 % or 0.1 % of the rated current of the wind farm. These very low limited values often gives the problems for the connection of the wind farms to the grid.

3 2. Investigations

Possibly reasons for the exceeding of the limits could be:

- Harmonic emission of wind turbine is too high
- Limits are too low
- Measurement is disturbed by background noise or resonances
- Summation law is not correct
- Grid impedances for higher frequencies are estimated as too high
- Inverters are not like ideal current sources

To solve the problems the working group has to investigate the following issues:

- Optimisation of harmonic measurements at single wind turbines. Background noise (harmonic voltages in the grid) disturbs the measurement of the harmonic currents, see figure 3. Thus it is necessary to find methods, how to separate background noise from the real harmonic currents, caused by the wind turbine. Furthermore

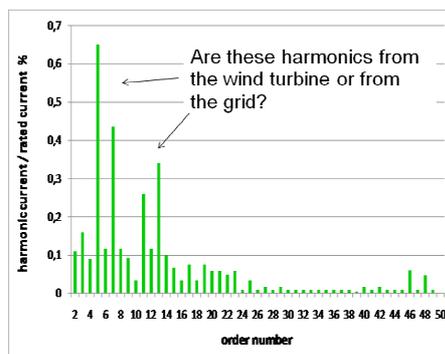


Figure 3: Harmonic current emission of a single wind turbine, possibly disturbed by 5th, 7th, 11th and 13th harmonic voltages, already existing in the grid.

local resonance phenomena could influence the harmonic current emission of the wind turbine.

- Standard voltage transducers at medium voltage systems do not allow exact measurements of harmonic voltages and thus of harmonic phase angles for frequencies above about 2 kHz due to their poor frequency response characteristic.
- The standard assessment method for the calculation of the harmonic currents of the wind farm from the harmonic emission of the single wind turbine must be verified. In some cases it was recognized, that the really measured harmonic currents at the wind farm are different from the calculation from the emission of single wind turbines by standard methods. Thus the existing methods must be verified and possibly corrected.
- The general assessment method is based on the rule, that the single wind turbine is an ideal current source for harmonics. This simplifies the assessment of the harmonic currents of a wind farm, but it seems that it does not correspond to the real behaviour. The inverter systems may be more like voltage sources for harmonics, but not ideal voltage sources, see figure 4.
- Drawing-up of a procedure for measurements and assessment of harmonics of the whole wind farm. In some cases it will be necessary to make measurements at the wind farm to verify the harmonic current emission.

Practical measurements on wind farms and wind turbines shall give a data base for further theoretical investigations. The aim is, to find methods for the

- Necessary Investigations for the determination (separation) of background noise:

 - Filter
 - Harmonics power flow direction
 - Diurnal pattern
 - Shutting down neighbouring turbines or loads
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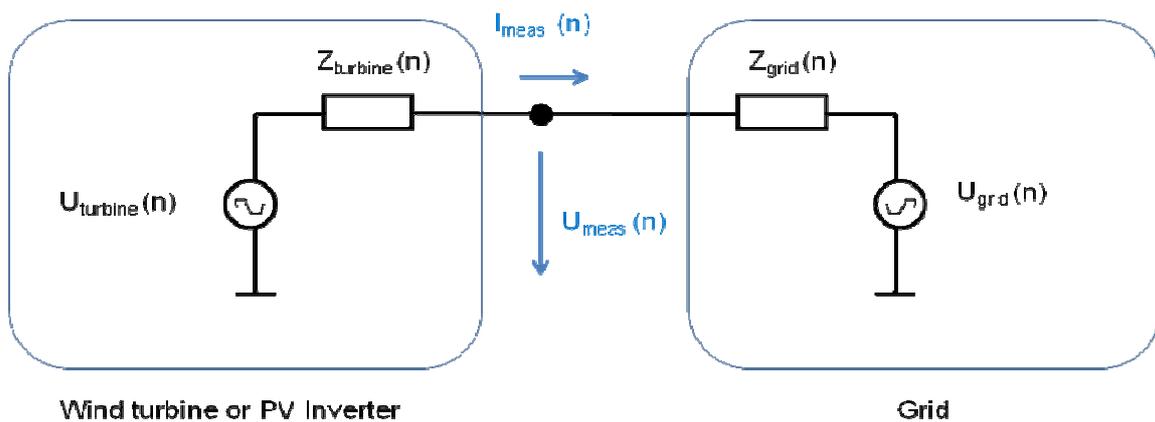


Figure 4: Wind turbine or PV Inverter as non-ideal harmonic current or voltage source.

assessment of the wind farm harmonic currents, which are more realistic than the actual, more conservative methods.

4 Conclusion

The SDL WindV /1/ requires the assessment of harmonic emission of wind farms. But the procedures for the assessment are partly not defined or not checked. Further on the measurement of harmonic currents of single wind turbines is influenced by background noise, harmonic voltages from other generators and consumers. This makes the assessment of the harmonic emission of wind farms difficult and led to the situation that in often cases the certification calculations showed higher harmonic current emission for wind farms than the limited values.

A new working group was established in 2010 under the FGW TR3 /3/. This working group has to investigate:

- Common procedures for the assessment of harmonic emission
- Summation law
- Influence of background noise on harmonic current measurements
- A new model of the wind turbine, where the wind turbine is simulated as nonideal harmonic source
- Procedure to determine the values of the voltage resp. current source and the impedances.

The estimated time schedule for this work is 2 – 3 years.

5 Literature

- [1] Verordnung zu Systemdienstleistungen durch Windenergieanlagen (SDLWindV) 3.Juli 2009
- [2] Technische Richtlinie Erzeugungsanlagen am Mittelspannungsnetz, Richtlinie für Anschluss

und Parallelbetrieb von Erzeugungsanlagen am Mittelspannungsnetz, Ausgabe Juni 2008; Herausgeber: BDEW, Bundesverband der Energie- und Wasserwirtschaft e. V

- [3] Technische Richtlinien für Windenergieanlagen; Teil 3: Bestimmung der Elektrischen Eigenschaften von Erzeugungseinheiten am Mittel-, Hoch- und Höchstspannungsnetz, Rev. 21. Fördergesellschaft Windenergie, FGW.
- [4] IEC 61400-21: Wind turbine generator systems – Part 21: Measurement and assessment of power quality characteristics of grid connected wind turbines., Ed. 2, 2008.