Harmonic current emission of wind farms

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Summary:
The testing but also the assessment of harmonic current emission of wind farms gives still problems. One of the main reasons is background noise during the measurement of harmonic emission at wind turbines or wind farms. This Paper will discuss the influence of the background noise and will give ideas, how to overcome or eliminate the background noise. Examples of harmonic measurements at wind farms and at single wind turbines including background noise are shown.

1 Introduction
Background noise often give influence into the measurement of harmonic current emission of wind turbines and wind farms. The background noise is due to harmonic voltages in the grid, which are from loads and generation units. These harmonic voltages lead to harmonic currents for example into the harmonic filter or into other components of a wind turbine. But also for wind farms these harmonic voltages lead to additional harmonic currents into the cabling of the wind farm.

Due to the strong limits for harmonic currents by the grid operators, it is essential to identify the effect of the background noise on harmonic current measurements.

2 Harmonic measurements at single wind turbines
The electrical characteristics of single wind turbines are tested during the type testing procedure. The measurement of harmonic current emission is a part of these tests.

In general the measurements are taken at the low voltage or at the medium voltage side of the wind turbine transformer, as indicated in figure 1. For both measurements points the harmonic current measurements includes the harmonics, which are generated by the wind turbine. (e.g. inverter system, own consumption) and which are from the background noise (coming from the grid and flowing into the harmonic filter or into other components of the wind turbine. From the measurement both parts (generated by the wind turbine and coming from the background noise) can not be separated.

To identify the background noise it is necessary to make special tests and special analysis. One of these special tests is shown in figure 2. The red bars of the bar graph give the harmonic current and harmonic voltage measurement for the 2nd to 50th order (100 Hz to 2.5 kHz) for normal operation of the wind turbine. The blue bars give the harmonic current and voltage measurement during a special operation, where only the harmonic filter and the own consumption is switched-on. The generation system and the inverter system are not connected during this operation mode. During this period, the inverter system does not generate harmonic currents, because it is not connected. But the background noise leads to a harmonic current flow into the harmonic filter of the wind turbine. The harmonic currents from the own consumption of the wind turbine can be neglected in the case, because it was shown, that their influence was very low.

Figure 1: Procedure for the determination of harmonics of a wind farm.
The comparison of the blue and the red bars in figure 2 shows:

- For some of the harmonic orders (especially between 19th and 27th order) the red and the blue bars for the harmonic currents are nearly equal. That means that the background noise has an essential influence for these harmonic orders.
- Even for the 45th and 47th order of harmonic currents, which are typically generated by the inverter, the blue and the red bars are nearly equal.
- In some of these cases the harmonic voltages show the same height of the red and the blue bars. That would mean, that the inverter has no or only low influence on harmonic current and harmonic voltage at these frequencies.
- For the 45th and 47th order the harmonic voltages are much higher, when the inverter is connected, although the harmonic currents show similarly heights of the bars.

Further investigations are necessary, for example the investigation of the harmonic phase angles, to clearly identify the influence of the background noise.

### 3 Harmonic measurements at wind farms

The results of an harmonic measurement at a whole wind farm is shown in figure 3. The measurement was performed at the 20 kV medium voltage side of the wind farm. The red bars give the harmonic currents and harmonic voltages for the 2nd to the 50th order (100 Hz to 2.5 kHz) for full load operation of the wind farm. The blue bars give the harmonic currents and voltages during a time period, where the wind turbines of the wind farm are disconnect. That means during this time period, only the wind turbine transformers, the own consumption of the wind turbines and the wind farm cabling is connected to the grid.

The results of these measurements are as follows:

- The 5th and 7th harmonic order show much higher harmonic currents and voltages, when the wind turbines are disconnected.
- Some other harmonic orders show similar bars for voltages and currents, like the 11th and 13th order.

It is obvious, that the inverter reduces the 5th and 7th harmonic voltages.

The same behaviour can be seen for the interharmonic currents and voltages for the same measurements, as shown in figure 4. Here one further phenomenon occurred:

The interharmonic voltage at 275 Hz is much higher, when the wind turbines are disconnected, although the current at 275 Hz is lower, when the wind turbines are disconnected.
Figure 3: Harmonic voltage and current measurement (integer harmonics) of a wind farm, disturbed by background noise.

Figure 4: Harmonic currents and voltages (interharmonics) of a wind farm.