Power Quality and Electrical Characteristics of Renewable Energy Systems; Can we use the Experience of the Wind Energy?

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Summary:

This paper discusses, how the existing power quality measurement guidelines for wind turbines can be used for other renewable energy systems. The main aspect are the flicker measurements. Difficulties for use of the requirements at different voltage levels will be shown as well as how these difficulties possibly could be solved. Measurement results will illustrate the investigations.

1 Introduction

Some new grid codes came up within the last year. They give specifications for the grid connection of wind farms but also for other renewable generation, like electrical energy from photovoltaic (PV) or biomass.

There is a lot of experience of the electrical characteristics of wind farms from the power quality measurements of wind turbines and farms of the last 15 years. New experience was collected concerning the capability of wind farms for the support of the grid (reactive power and voltage control, during grid faults, etc.).

Up to now the experience of the electrical characteristics (power quality) of other renewable energy generation is only low. Thus measurements are required for such renewable generation systems. The main question is, if the measurement guidelines for wind turbines, like the IEC61400-21 [1] or the German Technical guidelines [2] and [3], are adequate for the measurement of the electrical characteristics of the other renewable generation systems and possibly further generation, like co-generation. Detailed investigations are necessary.

The main differences concerning the grid connection of wind energy and other renewables are:

- grid connection point is different (low voltage, medium voltage, high voltage connection) and thus analysis tools must be adapted
- the energy source is different (eq. Solar instead of wind) and thus statistical analysis must be adapted
- parts of the energy systems changes frequently (inverters for PV)
- Background noise of the grid
- ....

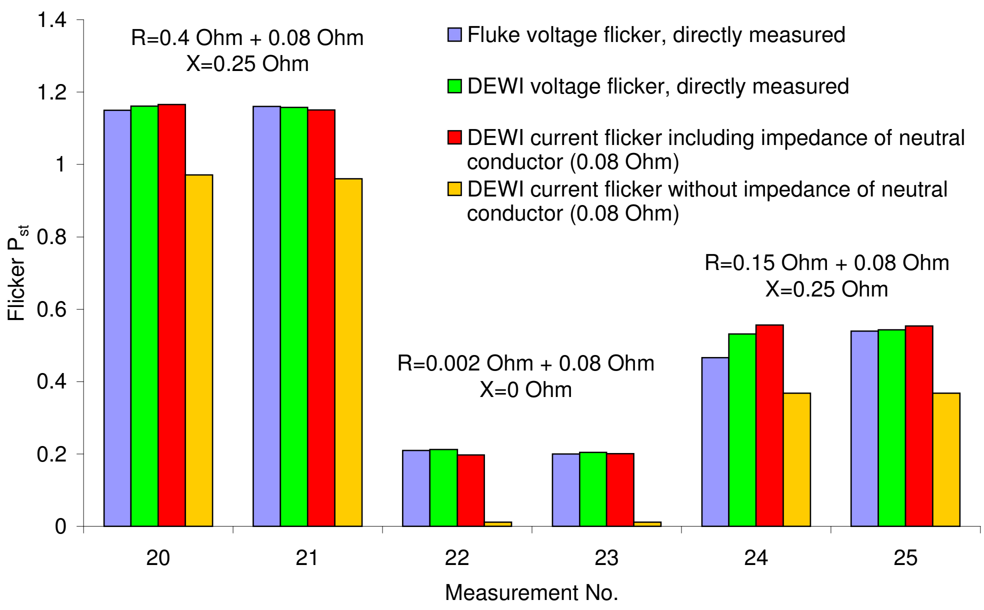

Figure 1: Comparison of flicker Pst values (from voltage flicker and from current flicker measurments) for calculation with and without the impedance of the neutral conductor

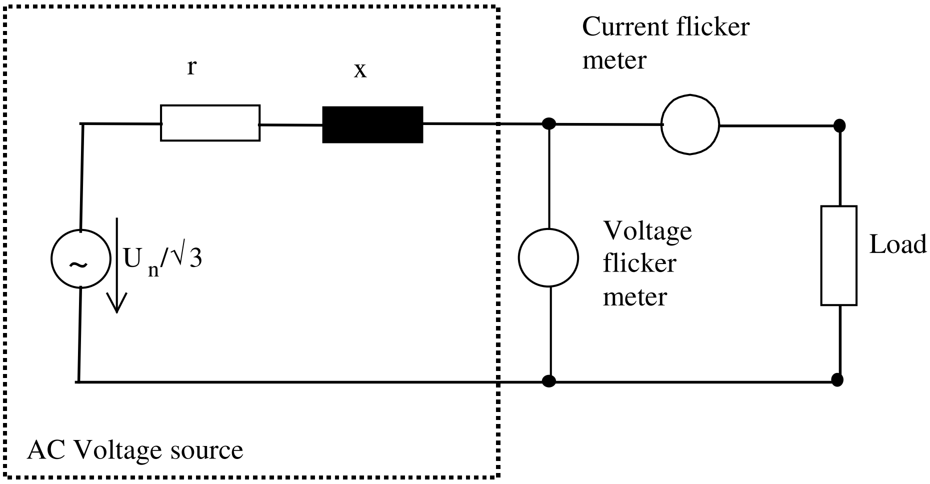

Figure 2: Schematic diagram of the test circuit including the AC voltage source, voltage flicker meter, current flicker meter and load.

2 Voltage level

The IEC 61400-21 gives the requirements for the measurement of the electrical characteristics of wind turbines on the assumption, that the grid coonection of the wind turbines is at medium or high voltage grid. Thus the guideline defines a grid model for the flicker evaluation, where no impedance is included in the neutral conductor. Due to the effect, that wind turbines are connected at three phases, where the neutral takes in general no current, this simplification of the grid model is correct.

But for low voltage connection there could be a current through the neutral, thus also the impedance of the neutral must be taken into account. This requires a different grid model, than given in the IEC61400-21.

Figure 1 shows an example of six flicker measurements (No. 20 –25) at low voltage system. A load was connected to a low voltage AC source, where the impedances could be changed, as given in the figure 2. The load was fluctuating, which gave a certain flicker level. For each measurement two flicker instruments, based on voltage signals (voltage flicker) and two instruments, based on current signals (current flicker) are shown. The grid impedance angle was changed for each second measurment, as given in the diagram. As it can be seen in the diagram of figure 1 the voltage flicker instruments show results, which are very similar, only measurement No. 24 shows slightly differences. The current flicker analysis, where the Neutral was taken into account (red column) shows very similar flicker

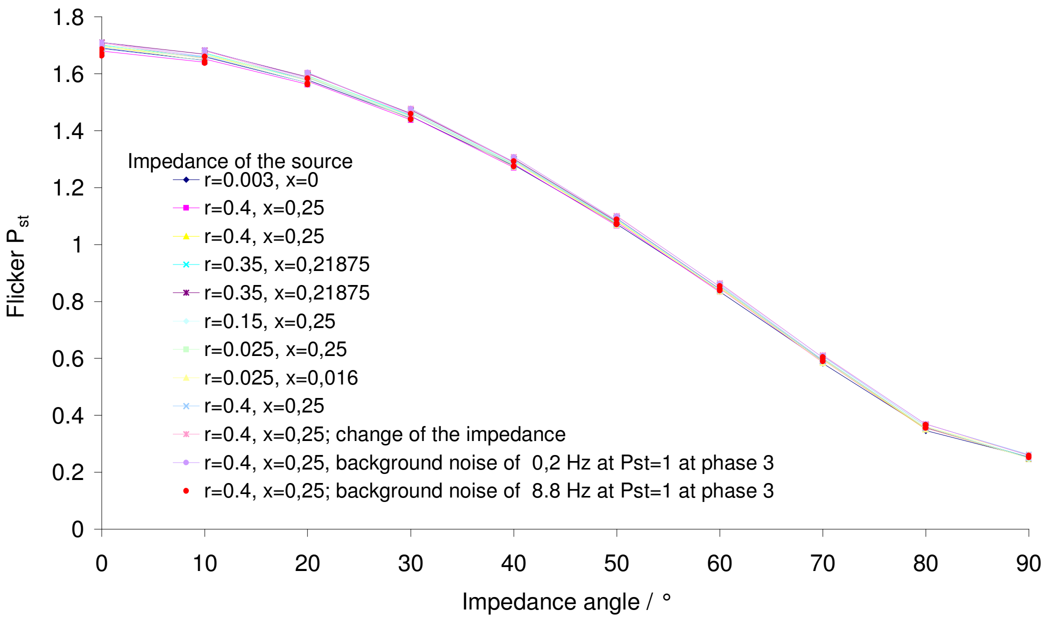

Figure 3: Test results of the current flicker meter, when the grid impedances of the voltage source are varied or when additional flicker is distorting the voltage source. For each of the tests the current flicker analysis shows the same results and the same dependency on the angle of the grid impedance.

values as the voltage flicker instruments. Only the 4th column (orange coloured) shows a clear deviation, so that the flicker value is much lower than the others. This is due the effect, that the impedance of the neutral was not taken into account for this current flicker calculation.

3 Influence on grid impedance angle and background flicker

Background flicker, which comes from other flicker sources and which gives a voltage fluctuation in the grid, is a problem for flicker measurements, based on voltage signals. Thus equipment for the connection at low voltage systems is in general tested concerning flicker at an undistorted AC source, to avoid background flicker. These AC sources are of course an ideal method to measure the power quality of electrical equipment. But as soon as you need to test electrical equipment with some kW power, the AC sources are expensive. The current flicker (flicker analysis, based on current measurements) is less cost-intensive, because the equipment can be connected to the real grid, but it can also be effected by background flicker or voltage changes.

The results of measurements of a fluctuating load with a certain flicker level is shown in Figure 3. The load is tested at an AC voltage source with different grid impedances. In total 12 tests were made, where the impedance of the voltage source was changed, beginning with r=0.003 Ohm and x=0 Ohm until r=0.4 Ohm and x=0.25 Ohm, as given in the diagram. The current flicker can be analysed for grid impedances and for impedance angles, independent from the real impedances of the voltage source. In this case the current flicker is calculated for all tests for the same impedance, where the absolute value of the grid impedance is 0.47 Ohm and the impedance angle changes from 0° up to 90 °. The result of the tests is, that the analysed current flicker is nearly the same for all of the tests. This means, that the current flicker measurement is nearly independent from the real grid impedance of the voltage source or the grid, where the load or generator is connected.

In figure 3 the two last tests were performed, where the voltage source was distorted with an additional voltage flicker at phase 3. This voltage flicker had an level of P_{st}=1 with a rectangular voltage fluctuation of 0.2 Hz, see figure 4. As it can be seen in Figure 3 the results of the current flicker instrument are the same than the results of the other tests. This indicates, that the current flicker is mainly independent from voltage fluctuations of the source or of the grid and thus independent from the background flicker.

4 Conclusion

A grid connection point at the low voltage side requires a different definition of the grid model for flicker calculation (current flicker). The present procedure for medium voltage is without a grid impedance at neutral conductor. The investigation shows a significant difference without the grid impedance in neutral (yellow stack) as the red one including the impedance at neutral. A comparison to the voltage flicker shows an acceptable correlation of the current

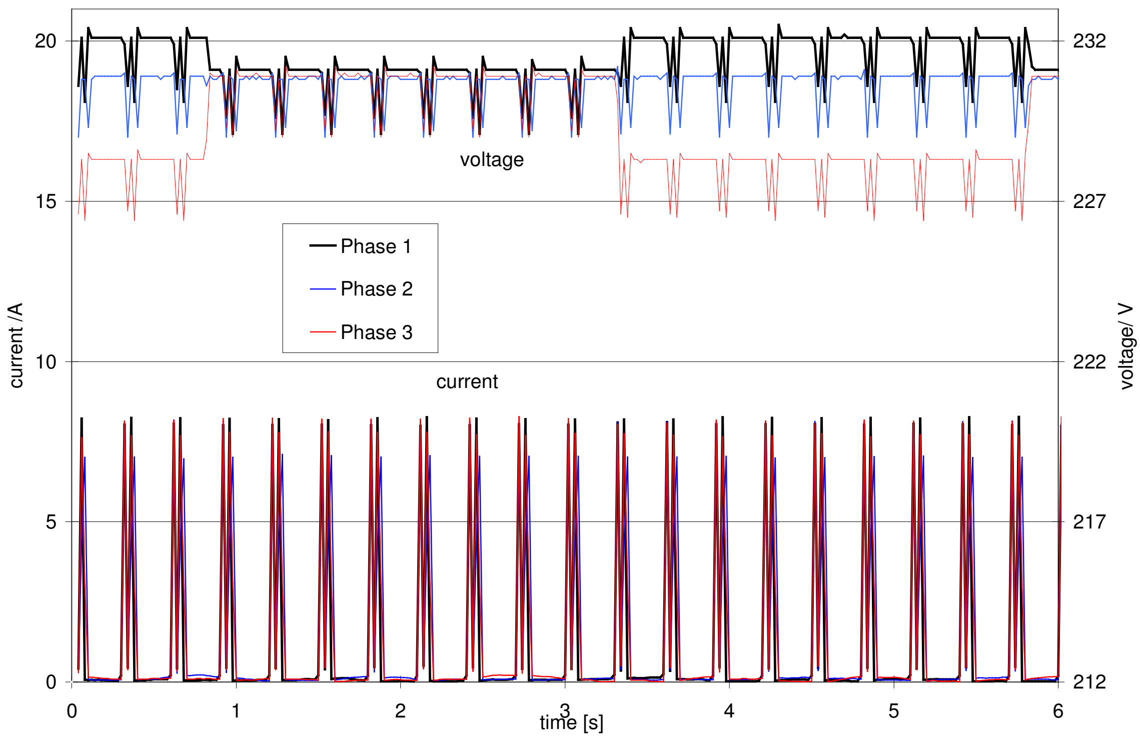

Figure 4: Measured voltage and current signals as rms values. The load is a heater, which is switched on and off for some grid periods to control the temperature. As a distortion the voltage of phase 3 is modulated with a rectangular voltage signal of 0.2 Hz. This distortion influences the voltage flicker instrument, but the current flicker instrument only analysis the current, which is nearly undisturbed from the voltage distortion.

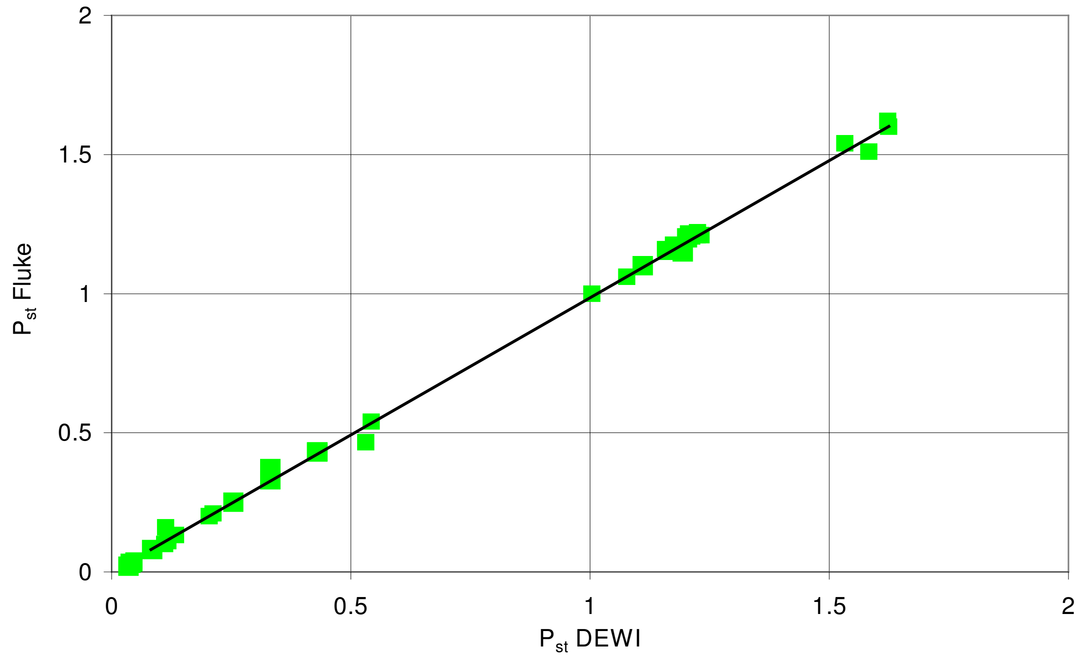

Figure 5: The voltage flicker analysis tool of DEWI is comparable to a standard flicker meter, used at low voltage. Several measurements (each dot shows one measurment result) show a maximum difference between both instruments of 1.5 % for flicker values

flicker, where the neutral impedance was included.

Background flicker and change of the present grid impedance has no significant influence on the current flicker. Tests with several grid impedances and additional background noise do not influence the results of the current flicker. For each test the current flicker analysis show the same results and the same dependency on the angle of the grid impedance.

5 Literature

[1] IEC 61400-21: Wind turbine generator systems – Part 21: Measurement and assessment of power quality characteristics of grid connected wind turbines., Ed. 2, 2008.

[2] Technische Richtlinien für Windenergieanlagen; Teil 3: Bestimmung der Elektrischen Eigenschaften von Erzeugungseinheiten am Mittel-, Hoch- und Höchstspannungsnetz, Rev. 19. Fördergesellschaft Windenergie, FGW.