EMC of Harmonic and Transient Measurement Equipment in Offshore Wind Farms

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Abstract

The electromagnetic compatibility (EMC) and interference (EMI) aspects during the development, construction, testing and installation of a measurement system for multi-point, high-speed and long-term data logging is described in this paper. The presented measurement system was tested in a rough offshore environment at Avedøre Holme and Gunfleet Sands (see Figure 1) offshore wind farms. The paper clearly presents possible electromagnetic interference in wind turbines that can affect measurements. Also the application of appropriate mitigation techniques such as data acquisition board configuration, coaxial cable leading, as well as usage of EMC-proof boxes for high frequency measurements is described. Some measurement results focused on dealing with EMI are also presented and explained.

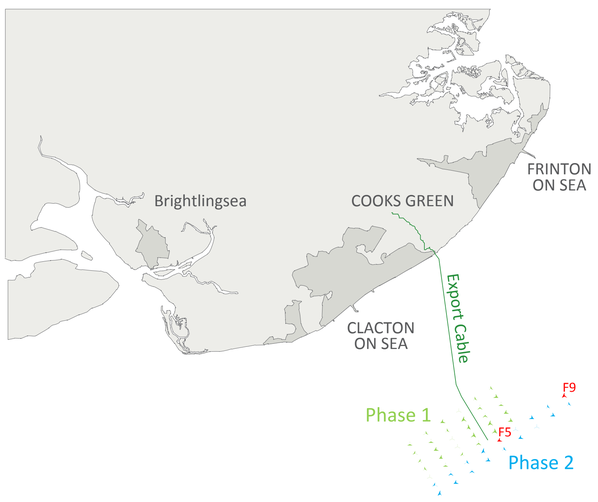

Figure 1 Gunfleet Sands Offshore Wind Farm and measurement points.

Objectives

The most likely scenario for incompatibility occurs when a relatively high power circuit (i.e. power converter) is located near a very sensitive receptor (e.g. sensors, cables, measuring head unit). Switch-mode high power density converters commonly used in nowadays wind turbines are potential generators of EMI due to the switching action of the converter. The switching action generates a spectrum of the switching frequency and its harmonics which can interfere the measurement process. The main purpose of presented studies is to develop and optimize measurements system for wind turbine measurements. Dealing with the EMI becomes crucial in case of harmonic measurements (low amplitude) and transient measurements (wide frequency spectrum).

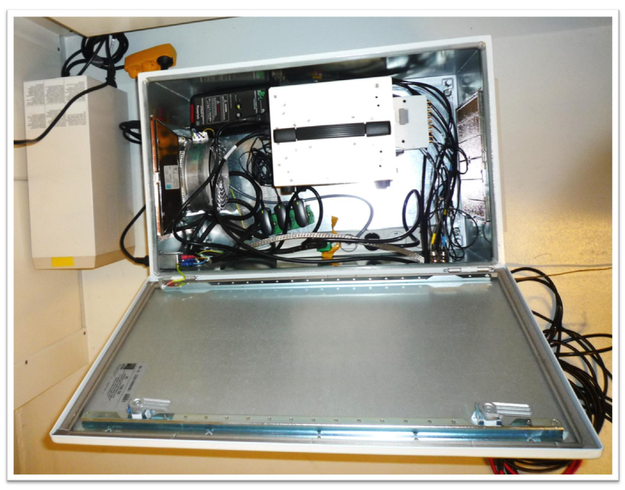

Figure 2 EMC box installed in the transformer platform at Gunfleet Sands Offshore Wind Farm.

Methods

If during measurements the transfer of electromagnetic energy from source (emitter) equipment, which in a wind turbines is the main power circuit, through a coupling path to a receptor (receiver), which is the measurement equipment, an EMI occurs.

Before any measurements are carried out it is recommended to perform test of EMI in the environment. Also in case of offshore measurements such test measurements were done. The first step is to perform open circuit measurements (see Figure 4) in the field and compare with laboratory expectations. According to central limit theorem one should expect normally distributed noise in open circuit measurements.

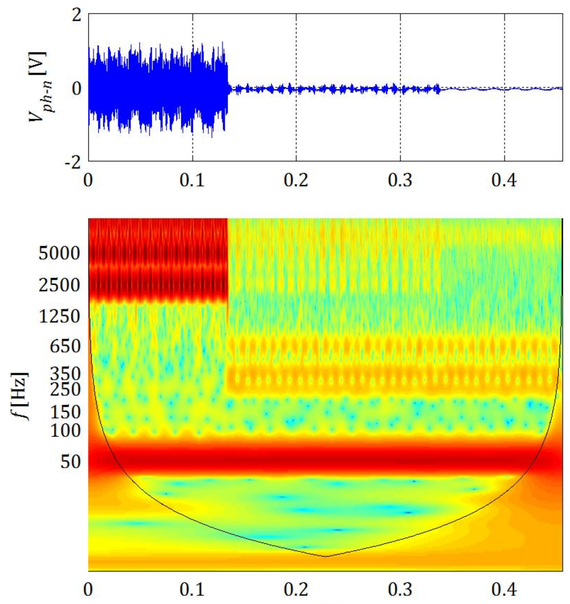

Figure 3 Continuous wavelet transform showing electromagnetic interference in the wind turbine.

All measurement set-ups face some level of error due to systematic (bias) and random (noise) error sources. By appropriate design of the system, sensor selection, sensor installation, sensor calibration, data acquisition (DAQ) calibration and an accurate synchronization board; the systematic and random error can be significantly reduced. Moreover, in order to reduce electromagnetic interference (EMI) from the power system to the measurement system, a custom made EMC box (see Figure 2) was designed as well as sophisticated shielding solutions.

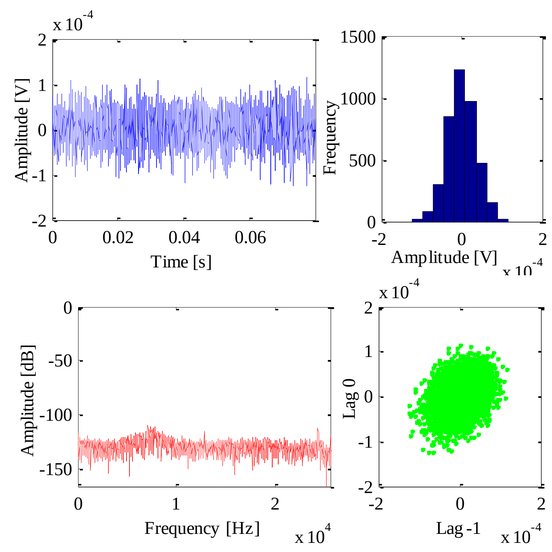

Figure 4 5 Open circuit measurement carried out in the lab and normally distributed histogram (top), open circuit measurements estimated spectrum and lag plot (bottom).

Results

It was observed that the crosstalk for adjacent channels is lower than -80dB in used for harmonic measurement dynamic signal acquisition board. Taking into consideration cross-talk from adjacent channels additional harmonic components can be seen at the top of Gaussian noise.

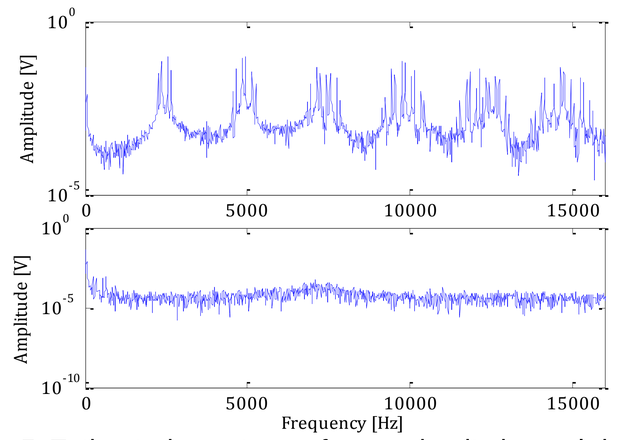

Figure 5 Estimated spectrum of open circuit channel during wind turbine production (top) and during not switching operation (bottom).

Time-frequency representation of measured continuous-time signals achieved using continuous wavelet transform is (Figure 3). The figure shows how different frequency components affects measured open circuit channel from the data acquisition board working inside the wind turbine. It can be seen that within the first period (0-0.14 s) the wind turbine is producing and frequency components around 2.5 kHz and 5 kHz generated by the modulator of the grid-side converter can be easily observed. Later the wind turbine is stopped and only harmonics affected by the external network can be measured.

This shows that the analysis of frequency components above 2 kHz can provide inaccurate results. This also indicates that sample rate above 4 kS/s/ch is not necessary for long-term harmonic measurements. Please note that in practise the noise level in the estimated spectrum is also strongly dependent on the window length of analysed signal.

Conclusions

EMI during measurements in offshore wind farms is an important issue and requires special considerations. It was shown that grid-side converters in wind turbines can be significant sources of possible interference during measurements. In case of harmonic measurements, where frequency components of amplitude around 2% of the nominal fundamental value are analysed, appropriate attenuation of interference distortions is crucial.

It was shown that dealing with different type of interference can by means of appropriate data acquisition system adjustment, shielding (see Figure 2), sensors adjustment and filtering. Of course sometimes it is difficult if even impossible to perfectly attenuate unwanted electromagnetic coupling. In that case appropriate interference assessment is needed which can be later taken into consideration during data processing and analysis.

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