GPS synchronisation of harmonic and transient measurements in offshore wind farms

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Abstract

The GPS synchronization challenges during the development, construction 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 (see Figure 1) and Gunfleet Sands Offshore wind farms. The paper will describe the application of GPS technology in synchronised measurements carried out at Avedøre Holme and Gunfleet Sands wind farms. Different aspects of software development and hardware configuration in order to optimise measurement system reliability during offshore measurements will be presented. Also real-life examples of results from both offshore measurement campaigns will be described. Some limitations and improvements of the measurement system will be explained based on measurements from both harmonic and transient measurements.

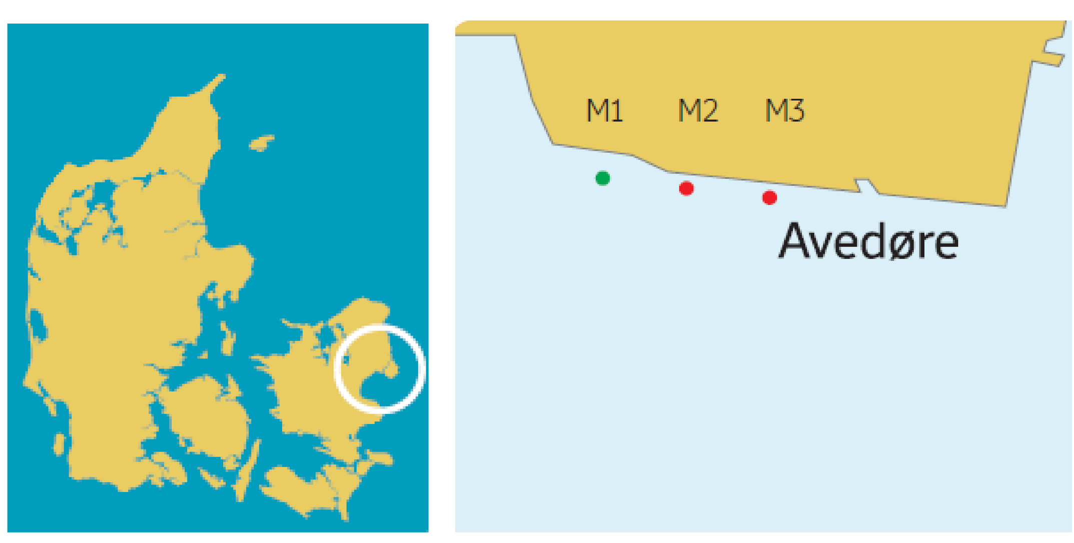

Figure 1 Avedøre Holme Offshore Wind Farm and measurement points.

Objectives

Accurate measurements of harmonic and transient phenomena in offshore wind farms are essential for data analysis and model creation/validation of components or subsystems. These models can be further used in simulation tools during the development of offshore wind farms. In order to observe the harmonic and transients in the collection grid without any misleading disturbances, a great deal of effort was taken to make the measurements as accurate as possible.

The measurement system developed here was designed taking into account the special application, requirements and environment of offshore wind farms (OWFs). Here, the access is limited due to weather conditions and significant operational costs; hence a robust and trustful measurement system is important. The synchronization of measurement systems in different locations is one important aspect taken into account in the development process of a flexible measurements system for harmonic and transient measurements in OWFs.

Methods

Synchronisation board

Specially designed EMC-proof boxes were equipped with cooling system in order to keep constant ambient temperature. If the ambient temperature differs from the calibration temperature by more than ±5˚ C the temperature compensated crystal oscillator (TCXO) will be affected by drift and introduce additional synchronization uncertainties.

Software development

In software development it is of special importance to implement synchronization support in the easiest way as possible. In case of transient measurements synchronization delays affected by the software layer can affect the whole measurement process. It was decided that the measurement software will start according to the time reference obtained from timing and synchronization board. A time reference is an external source of timestamp that provides periodic time updates. It is possible to provide time reference from GPS satellites, IEEE 1588 masters, or IRIG-B sources. As mentioned earlier each of the sources provides periodic time updates. In case of GPS satellites broadcast the current time once per second, on the second's boundary. The synchronization board has the oscillator (clock) accuracy of 1ppm which provides accurate time reference every second (PPS).

Synchronisation uncertainties

Used for offshore measurement purposes receivers provide a 1 pps on-time pulse. The GPS receiver is limited to using SPS the uncertainty is defined by the top row in Table 1. It shows that there is a 50 % probability that a given on-time pulse from GPS will be within ±115 ns of UTC. The 1σ uncertainty of GPS (~68 % probability) is ±170 ns, and the 2σ uncertainty (95 %) is ±340 ns [3], [4].

Service	Uncertainty (ns) 50th percentile	Uncertainty (ns) 1σ	Uncertainty (ns) 2σ
SPS	±115	±170	±340
PPS	±68	±100	±200

Table 1 Timing uncertainty of GPS in One-Way Mode

To achieve uncertainties presented in Table 1 one has to calibrate receiver and antenna delays, and estimate synchronization errors. The antenna providing reliable performance in harsh radio frequency (RF) jamming environments was connected to the receiver and mounted outdoors where it had clear, unobstructed view of the sky. This condition can be easily satisfied in large OWFs situated far from natural barriers and effects such as multipath propagation [5] due to the signal reflection, and high dilution of precision (DOP) when detected satellites are close together in the sky, can be neglected. Positional accuracy was improved due to the fact that the WTs and the substation at GFS OWF are situated far from each other and naturally are far from multipath reflectors (see [6]).

Pulse-per-second signal accuracy measured during measurement campaign at Gunfleet Sands OWF is shown in Figure 2. The accuracy is even better than provided by the manufacturer (15 ns, 1σ).

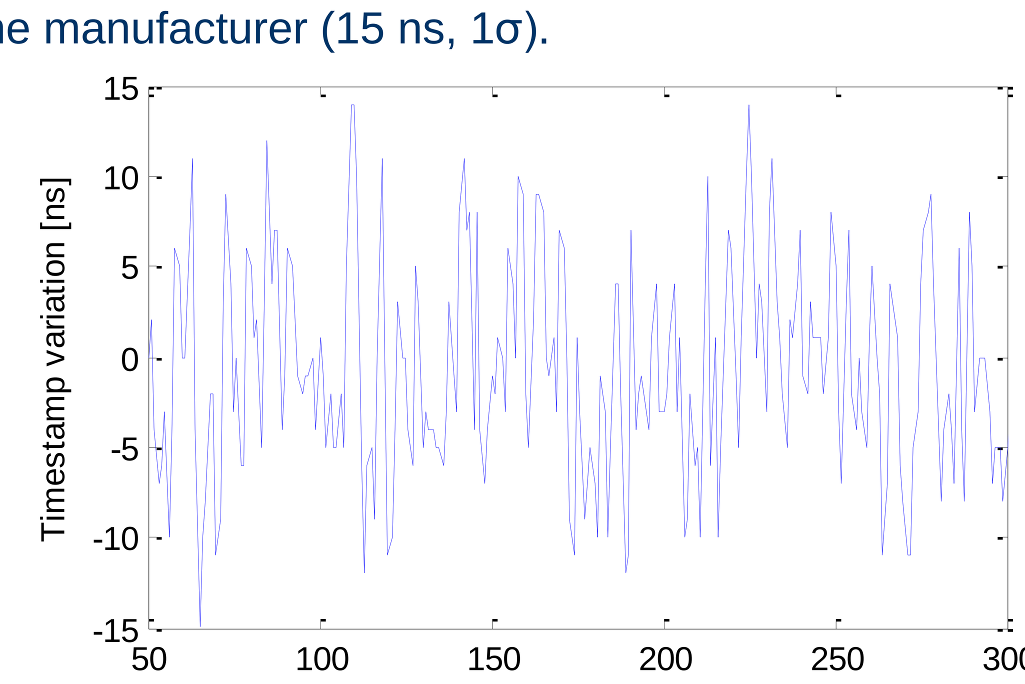

Figure 2 Variation of pulse-per-second signal synchronized with a GPS timestamp using phase-locked loop

Installation considerations

The measurement equipment in the wind turbines in Avedøre and Gunfleet Sands was installed in the basement of the wind turbine, where the service technicians do not require going often. In the transformer platform the measurement equipment was installed in the 33kV switchgear room, close to the voltage and current probes. It is important to mention, that the installation of the GPS antennas in Avedøre and Gunfleet Sands had to be done in open space outside the wind turbines and the transformer platform, in order to receive the best signal from the satellites. Nevertheless, the measurement equipment should be installed indoor, in a controlled environment. These two opposite requirements for the entire measurement system had to be fulfilled.

Results

Some of the transient measurements during the switching in of the VCB in the AVV wind turbine are shown in Figure 3. In this figure the voltage and current on the MV side of the transformer are shown, as well as the LV side voltage. It is possible to see in this figure the high frequency voltage oscillation caused by the pre-strike in the VCB that is transfer to the LV side as well as the inrush current of the transformer. The VCB model validation, as well as the wind turbine transformer and external grid validation has been reported in [7].

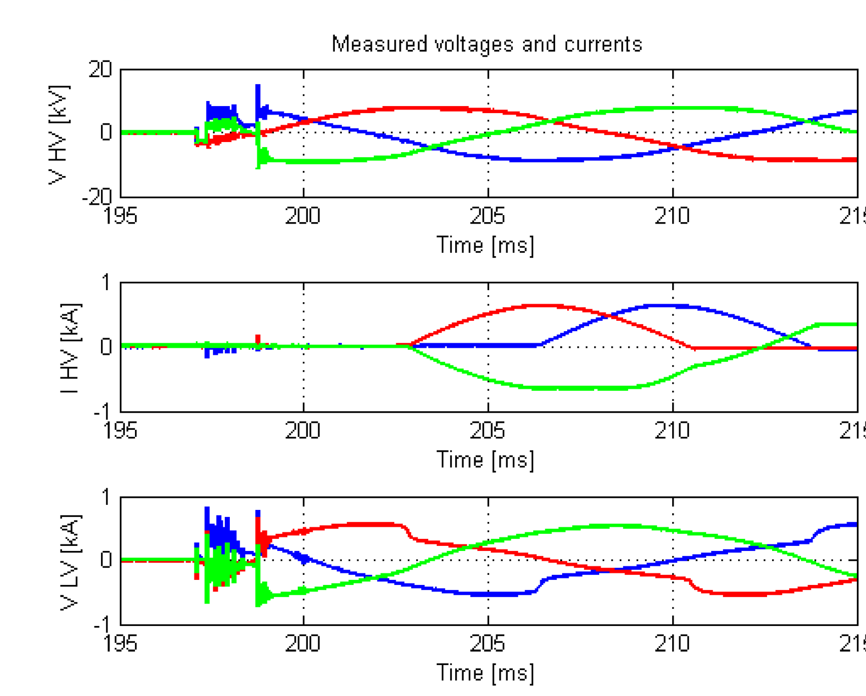

Figure 3 Measured three-phase voltages and currents, during the closing operation of the MV VCB in the wind turbine.

Discussion

During the removal of the measurement equipment in GFS, after 8 months of measurements, it was noticed that one of the GPS antennas was damaged. The antenna presented high level of corrosion in the metallic lower part of the antenna. Only the antenna in one of the wind turbines presented this corrosion. Due to this deterioration, the coaxial cable connected to the antenna, was also damaged, and had to be repaired afterwards. The metallic part of the antenna was simply cleaned. The damage in the antenna clearly shows the harsh environment to which the offshore wind turbines are subjected. In practice, this is solved by carefully isolating the equipment inside the turbine tower from the offshore environment.

Acknowledgment

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Gunfleet Sands Offshore Wind Farm

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