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Comparison of Asynchronous Sampling Correction Algorithms for Power Quality Measurements Under Realistic Conditions

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Introduction

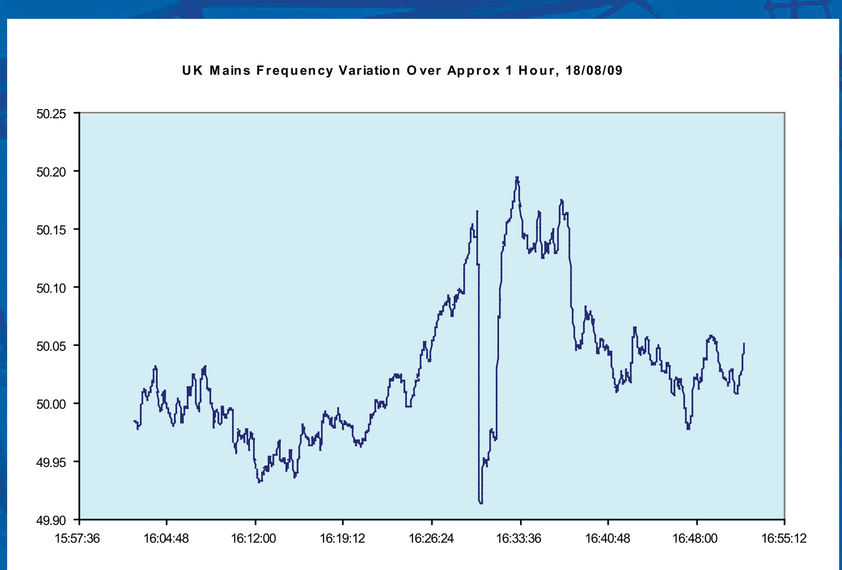
Sampling based power quality measurements in the laboratory are usually performed using a clock signal that can be readily synchronized to the signal under analysis. However in some circumstances synchronization to the frequency of the signal under analysis is not possible. Under these conditions, some means of correcting for the lack of synchronization is required for the accurate measurement of power quality parameters.

When making power quality measurements on the electricity supply network, this problem is further exacerbated by factors such as noise and interference and fluctuations in amplitude, phase and frequency. Under these conditions correction algorithms and synchronization techniques may not perform well.

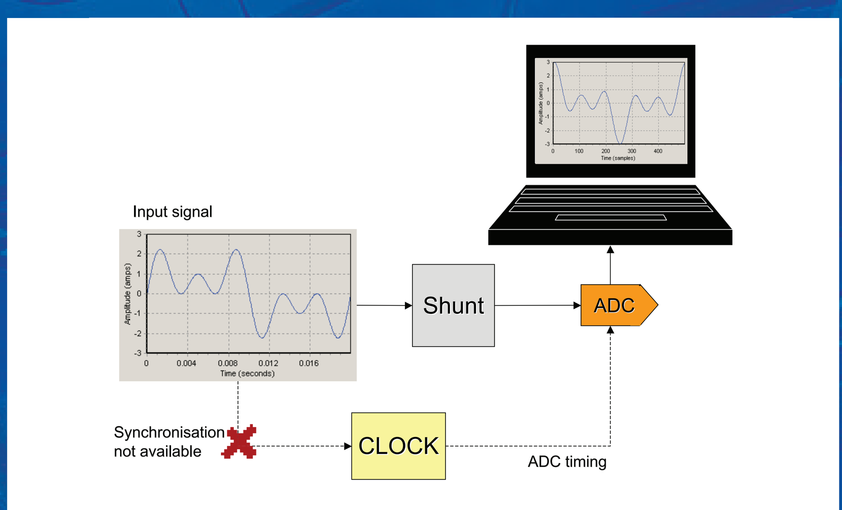
The intention of the presented work is to compare several approaches for correcting for errors in measurements of harmonics caused by asynchronous sampling of typical mains-borne waveforms. The tested algorithms were selected as examples of techniques which employ different principles of operation and are suited to different power quality events and measurement conditions.

The five different techniques are applied to a number of real sampled signals and simulated signals. These signals are intended to represent those that are likely to be encountered in power quality measurements on the electricity supply network. The algorithms' ability to recover the frequency and harmonic amplitudes and phases were assessed for these waveforms with varying levels of noise and amplitude, phase and frequency fluctuation.

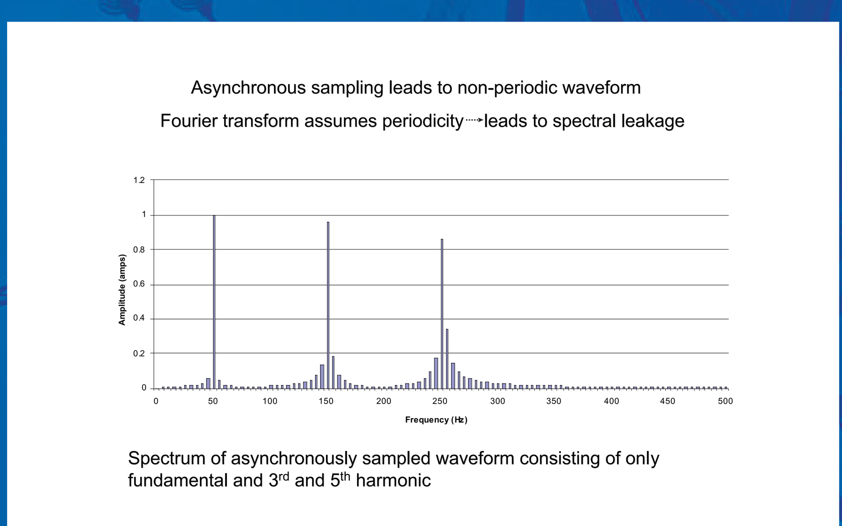
Mains frequency variation



Non-synchronised sampling measurement system



Asynchronous sampling errors – Harmonics



Correction algorithms

- Many algorithms are available
- 5 tested under realistic conditions and common power quality problems
- Phase Sensitive Frequency Estimation with interpolated phase (PSFEi) [1], [2]
- Time Domain Interpolation and Scanning (TDIS) [3]
- Dynamic Segmented Phase Shift/Harmonic Best Fit (D-SPS/HBF) – Under development
- 4 Parameter Sine Fit (4PSF) [4]
- Quinn Estimator [5]

Correction algorithms – Strengths and weaknesses

The algorithms have varying strengths and weaknesses and can be selected for use depending on conditions and application.

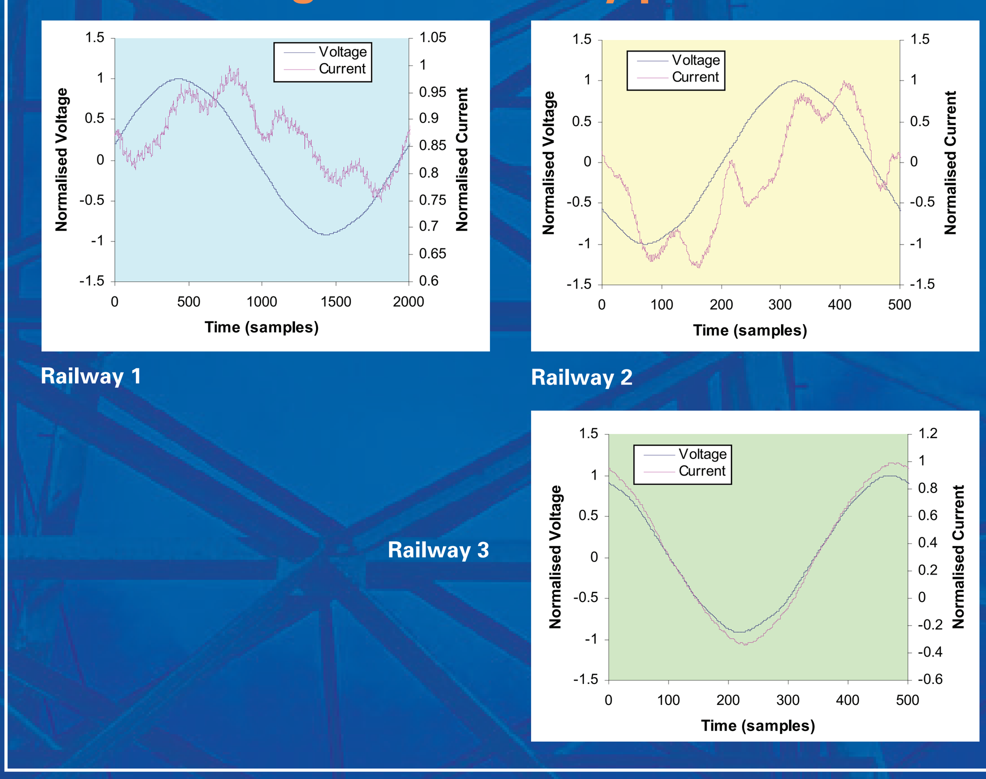
Three new algorithms were developed for the project:

- The **PSFEi** has excellent all round performance and computational efficiency and works best under high noise levels.
- The **TDIS** algorithm is a generic correction technique, and is not limited to recovering only frequency domain information. The time domain interpolation can be combined with the frequency estimation of any of the other algorithms to correct any band-limited waveform.
- The **D-SPS/HBF** algorithm is still under development and requires only half a cycle to obtain a frequency estimate and so is best suited to short term events such as short duration dips and swells.

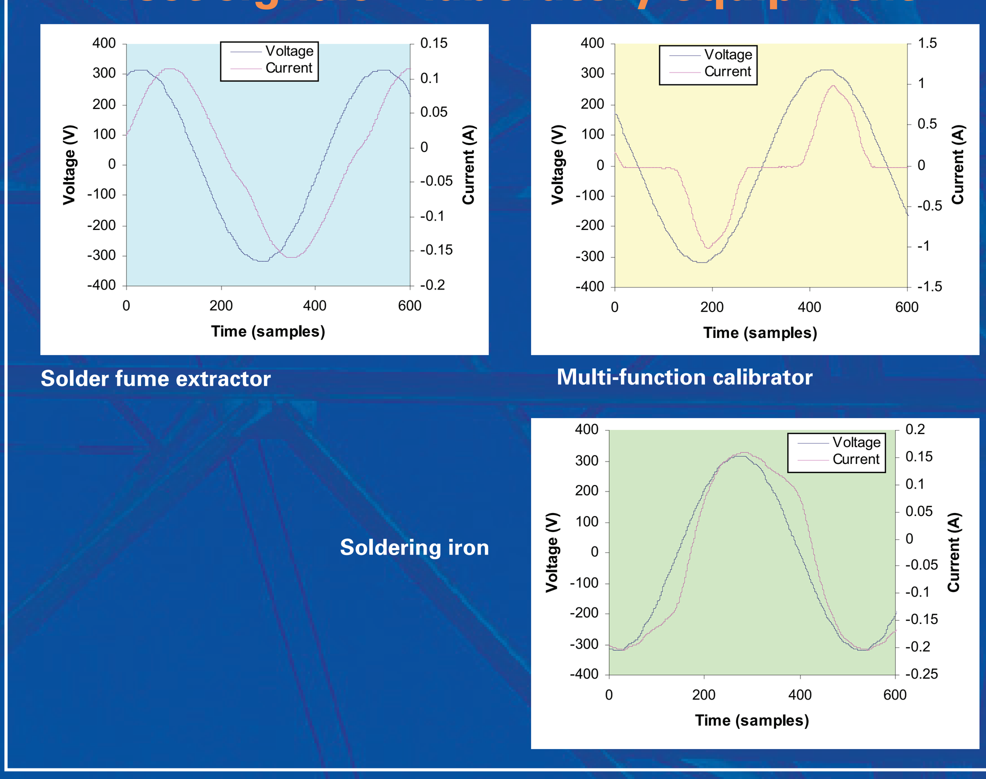
Two existing algorithms were also tested:

- The **4PSF** is a standard method, a benchmark against which all algorithms can be judged.
- The **Quinn estimator** is extremely efficient and less sensitive to phase variations and phase noise. However, it requires a relatively large number of cycles to show its best performance.

Test signals – railway power line



Test signals – laboratory equipment



Results – Real signals – Differences between current and voltage waveforms

Estimated frequency errors ($\Delta f/f$)

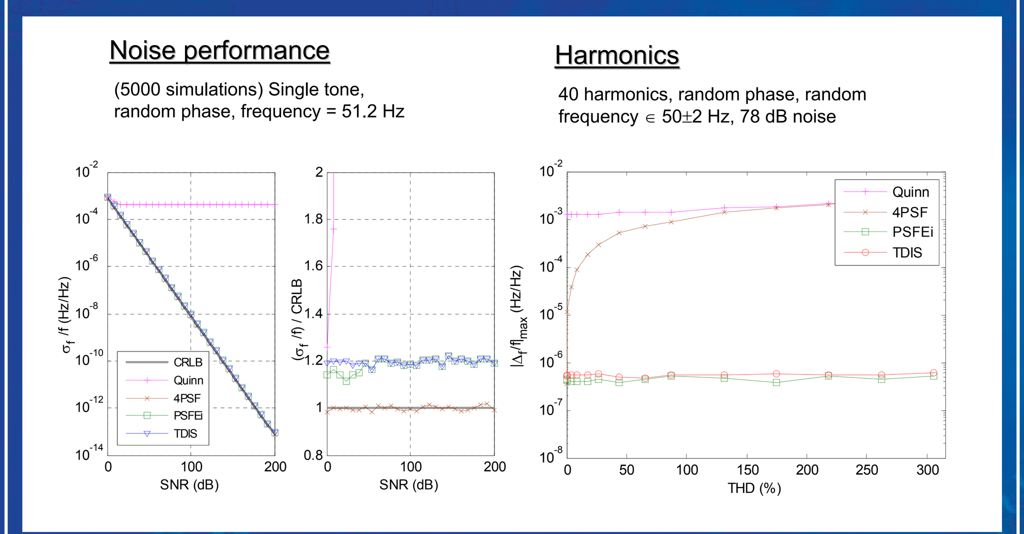
Test waveform \ Algorithm	PSFEi	TDIS	D-SPS/HBF[1]	4PSF	Quinn
Fume	3.56E-07	3.14E-07	1.78E-04	1.36E-06	9.58E-07
Solder	-1.40E-06	-7.12E-07	1.13E-05	-6.95E-07	-1.44E-06
Calibrator	1.57E-07	-2.28E-07	4.00E-03	6.02E-07	1.42E-06
Railway 1	6.10E-04	6.96E-04	-5.28E-03	1.01E-03	9.28E-04
Railway 2	-1.08E-06	-5.01E-06	-3.85E-03	-1.32E-06	-1.11E-06
Railway 3	-1.08E-06	-1.66E-06	-4.50E-04	-9.92E-07	1.42E-06

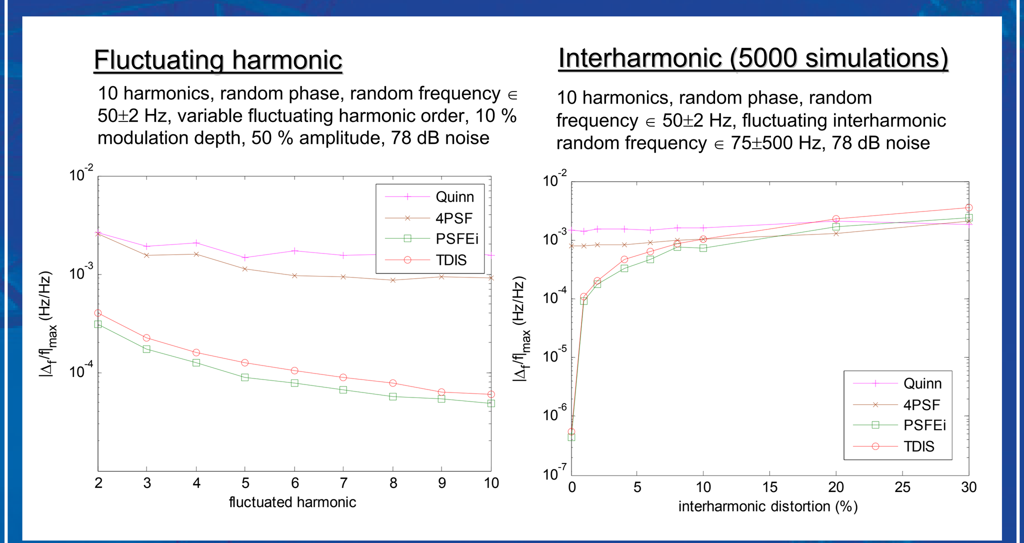
[1] D-SPS/HBF is a prototype algorithm, still under development

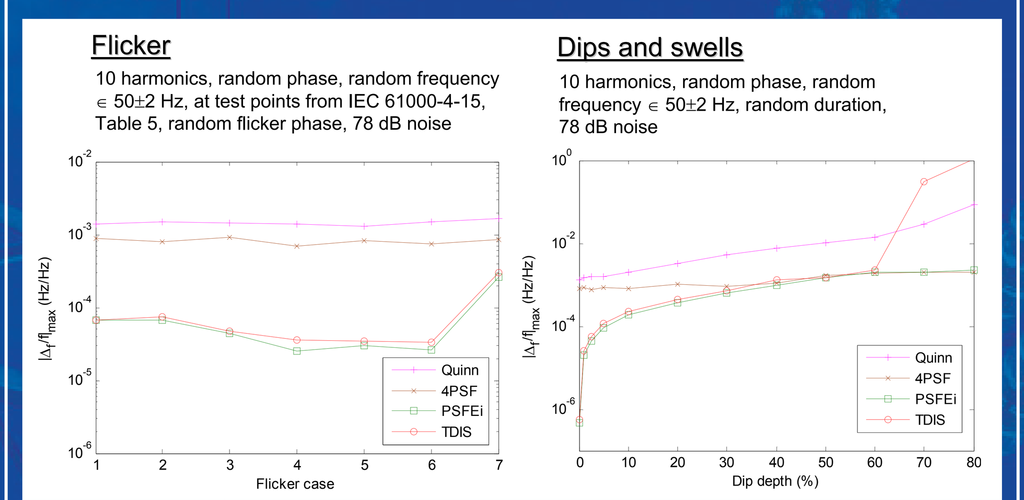
Test waveforms – Simulated power quality events

- Noise performance
- Steady state harmonics
- Fluctuating harmonics
- Interharmonics
- Flicker
- Dips and Swells

Frequency errors – Simulated power quality problems – Max of 2000 simulations 10000 samples / record Ts = 20 µs







Conclusion

A powerful suite of existing and new asynchronous sampling correction algorithms has been developed and tested for a range of power quality phenomena. The algorithms will shortly be ready for use in a power quality measurement system capable of on-site measurements in a variety of demanding conditions.

References

[1] R. Lapuh, "Phase Sensitive Frequency Estimator for Asynchronously Sampled Data," Conf. Dig. ERK 2009, Portorož, Slovenija, 23 Sept. 2009.

[2] R. Lapuh, "Phase estimation of asynchronously sampled signal using interpolated three-parameter sinewave fit technique," Conf. Dig. I2MTC 2010, Austin, Texas, May 2010

[3] P. Clarkson and P. S. Wright, "Evaluation of an Asynchronous Sampling Technique Suitable for Power Quality Measurements," Conf. Dig. IMEKO 2009, Lisbon, Portugal, Sept. 2009.

[4] IEEE Std. 1057-2007, "IEEE Standard for Digitizing Waveform Recorders," April 2008.

[5] B. G. Quinn, "Estimation of frequency, amplitude and phase from the DFT of a time series," IEEE Trans. Sig. Proc. Vol 45, No 3, pp. 814-817, Mar 1997.

National Measurement System

EURAMET European Association of National Metrology Institutes
EMRP European Metrology Research Programme ▸ Programme of EURAMET
MIRS SIQ
MIKES
INRiM Istituto Nazionale di Ricerca Metrologica