INTERHARMONICS ANALYSIS AND MEASUREMENT METHODS APPLIED TO MAINS FREQUENCY COMPLIANCE TESTING.

P.S.Wright.

National Physical Laboratory, Teddington, Middlesex TW11 0LW, UK
Email: paul.wright@npl.co.uk

Introduction

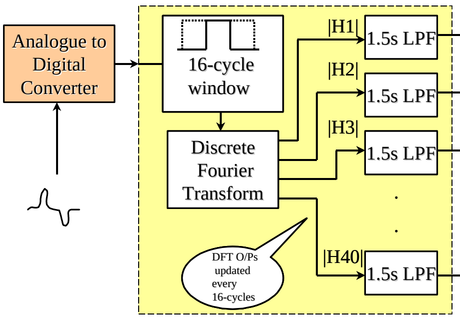
Recent changes to IEC standards will enforce the inclusion of interharmonic components in the measurement of harmonics for EMC compliance testing. This paper aims to explain these changes by contrasting the *existing method* that ignores interharmonics, with a *new method* that accounts for interharmonics.

In order to highlight the impact of the new method [1], the effects of interharmonics on a typical compliance measurement will be compared to the existing method [2].

The existing techniques used to calibrate harmonic analysers are invalidated by the inclusion of interharmonics in the analysers' measurement algorithm. New techniques developed and implemented at NPL to calibrate these new analysers under fluctuating signal conditions are discussed.

The Existing Harmonics Measurement Method (IEC61000-3-2: 2000-08).

In harmonic analysers developed prior to the recent changes to the standard [2], the signal to be measured is broken in to contiguous windowed sections, each 16 mains cycles in duration. For each window, a discrete Fourier transform (DFT) is applied in order to find the average harmonic components in the signal during the given window duration. To dampen any rapid changes in the signal, the harmonics resulting from each



windowed DFT, are individually smoothed using first order low pass filters each with 1.5 second time constant. This algorithm is depicted in Fig.1.

Figure 1, Existing IEC61000-4-7 Algorithm

The resulting 40 harmonics are then compared to limits published in the standard to determinate whether a given product under test is compliant with the EMC directive.

Interharmonics and DFT Frequency Resolution

Interharmonics feature prominently in the new method and it is important to describe their origin and the way that they are measured using the DFT.

As the name suggests, interharmonics are frequency components that exist in-between harmonics. They may result from independent non-synchronised signals such as communications tones or they may be artefacts of fluctuating harmonics resulting from the sidebands associated with the modulation of the harmonics. Interharmonics that exist between dc and the fundamental component are referred to as sub-harmonics.

The frequency resolution with which interharmonics can be measured depends on the number of fundamental cycles used in the DFT that is used to determine spectrum. For example if 10 cycles of a 50 Hz signal are analysed using a DFT, the resulting frequency components will be spaced at 5 Hz (50/10) intervals. As the harmonics of the 50 Hz signal occur every 50 Hz, there are nine measurable interharmonics equally spaced between each harmonic.

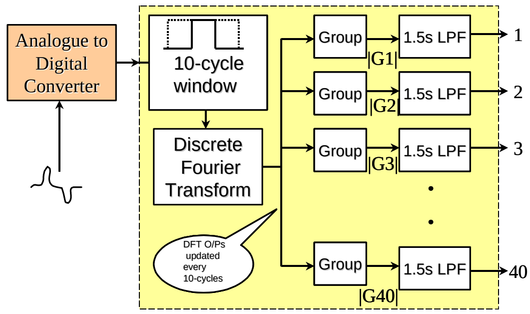
Harmonics Measurement Including Interharmonics Method (IEC61000-4-7: 2002).

As already discussed, the latest edition of the international standard [1] that specifies the design of harmonic analysers prescribes a new method that accounts for interharmonic components.

The new method (shown in Fig.2) breaks up the signal using

Figure 2, Interharmonic Grouping Algorithm

10-cycle windows (12 for 60Hz systems). As described above, the DFT of a 10-cycle window system results in nine measurable interharmonic components in-between each harmonic. In the existing measurement method these



interharmonics are simply discarded from the calculations. In the new method, the four interharmonics either side of each harmonic are grouped with that harmonic and combined by root sum squares (RSS). A given 5th interharmonic is halfway between two adjacent harmonics and its energy is halved and shared between the two harmonics using the same RSS method. The RSS values are then applied to the low pass filters as with the existing method.

Effects of the New Method

Manufacturers of harmonic analysers are now starting to release instruments that use the new method, although measurements using the existing method are still allowed under a transitional period which will run until the new standard is reviewed.

It is important to examine the effect of the new algorithm on a typical EMC compliance measurement. Under steady-state harmonic conditions the changes to the algorithm make no difference to the results; conversely a rapidly fluctuating current can give rise to considerable differences particularly for small magnitude harmonics.

In general, these rapid signal fluctuations give rise significant, but decaying sidebands around each harmonic. Despite their decay, these sidebands can exist with significant levels in the interharmonic bands. The RSS combination of this energy with any small amplitude harmonics (e.g. an even harmonic adjacent to significant odd harmonics) can give rise to serious variations between the existing and new methods in some cases of greater than 100%. Clearly such large differences will cause difficulties in compliance testing leading to pass/fail discrepancies depending on whether an electrical appliance is tested using the old or the new method. Further examples will be given at the conference.

Calibrating Analysers Employing the New Method

The new interharmonics method makes significant extra demands on the processing required by analysers and any problems with the instrumentation (e.g. speed issues, gaps between windows) cannot be detected with a steady-state test.

Calibration of harmonic analysers in the presence of fluctuating harmonics is therefore necessary which, in-turn requires the accurate measurement and characterisation of a given excitation waveform. As DFTs cannot be used reliably for fluctuating waveforms, special waveform transforms have been developed for this analysis [3].

Following analysis of the excitation signal, it is then necessary to determine the theoretical response of a perfect analyser to this waveform. This response is a function of the phase between the fluctuation function and the analyser windows [4]. For the existing analyser design, this function can be found using an approximation involving the mean value of each harmonic fluctuation function. The inclusion of interharmonics in the new method invalidates this approximation and complicates the analysis.

The new method has necessitated a major reworking of the NPL calibration method for fluctuating harmonics. This is summarised in the following steps:

- The development of a new method to determine the fluctuating harmonic modulation polynomials under more general conditions – Least Squares Polynomial Decomposition.

- A “Moving Sections” algorithm used to determine sections of the modulating polynomials whose size corresponds to the analysers’ window size. These sections can be efficiently shifted in time to find the analyser distribution function with phase.

- An analytical integration method to determine the interharmonic spectrum using the sectioned modulator equations. The interharmonics are then grouped as required by the IEC standard.

These techniques allow the analysis of a given calibration signal and also determine the response of an ideal analyser. Results from an analyser under test can then be fitted to this ideal response for calibration purposes.

Conclusion

Changes to the method of measurement of mains harmonics for EMC compliance testing are currently in transition and the new method using interharmonics will become mandatory in the near future. The extra processing requirements on harmonic analysers heighten the importance of their calibration under fluctuating conditions, as the performance of the new measurement method cannot be assessed using a steady state test.

The changes in the method have led to significant development of the calibration methods used to assess these analysers and the resulting techniques are now ready to be used for the calibration of this new generation of analysers.

Acknowledgment

This project was supported within the DTI National Measurement System Policy Unit's Programme for Electrical Metrology.

References

[1] IEC61000-4-7, Electromagnetic Compatibility (EMC) - Testing and measurement techniques -General guide on harmonics and inter-harmonics measurements and instrumentation for power supply systems and equipment connected thereto, Published by The International Electrotechnical Commission, 2002.

[2] IEC61000-3-2, ‘Electromagnetic Compatibility (EMC) Part 3-2: Limits – Limits for harmonic current emissions (equipment up to and including 16 A per phase)’ published by the International Electrotechnical Commission, Second Edition, 2000-08.

[3] Polynomial Decomposition of Smoothly Fluctuating Harmonic Waveforms Applied to the Calibration of Harmonic Analysers, P.S.Wright, IEEE Instrum. and Meas., Vol.54, No.2, April 2005.

[4] A method for the calibration of harmonic analysers using signals containing fluctuating harmonics in support of IEC61000-3-2, P.S.Wright, IEE Proc.-Sci. Meas Technol., Ready for publication Spring 2005.