

Calibration of IEC1000-3-2 Harmonic Analysers

P.S.Wright

1. Abstract

A new measurement system for the calibration of Harmonic Analysers to IEC 1000-3-2:1995 [1] is described. Details are given of the measuring system components and their use for the calibration of this type of device. The problems in measuring signals composed of fluctuating harmonics are discussed. A method of calibration for a special case of this type of signal is described.

2. Introduction and Background

In an attempt to regulate the growth of distorting loads on the electricity supply system, an IEC standard, IEC1000-3-2 has been published which prescribes limits on current harmonic pollution generated by a given electrical appliance.

In order to make compliance tests on these electrical appliances, new analysing instruments sometimes known as "Harmonic" or "Power Analysers" are now marketed to assess the various aspects of the load as prescribed in the standard. Unfortunately some of the measurements described in the standard have proved difficult to make in a traceable fashion. Hence the need has arisen to find a method to provide an calibration for these analysers.

This paper describes a new calibration system which is now available for use with these analysers.

3. Description of the Calibration System

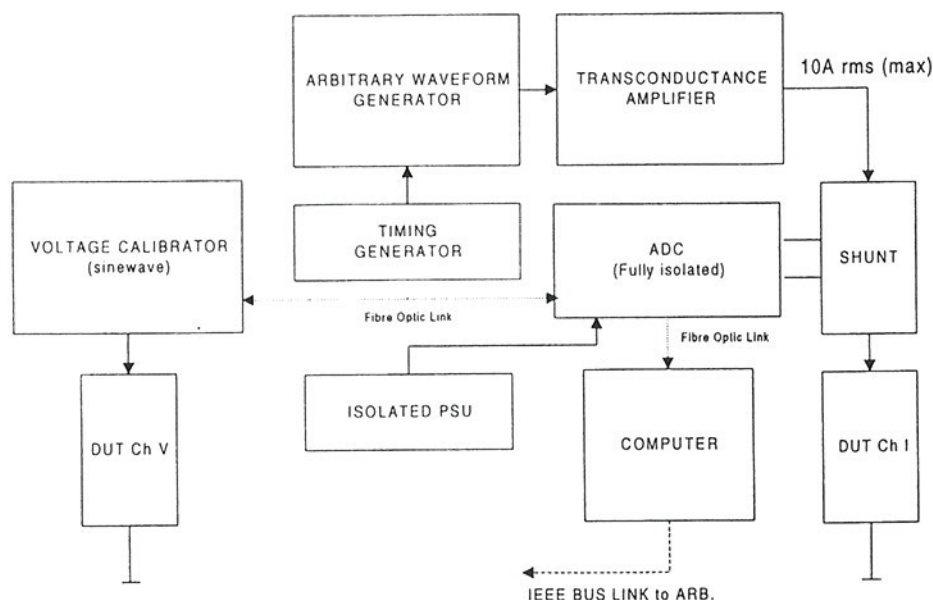


Figure 1, Harmonic Analyser Calibration System

P.S.Wright is with the National Physical Laboratory (NPL), Queens Road, Teddington, UK.

The calibration system is shown in Figure 1. The Device Under Test (DUT) is shown divided in to its separate voltage and current channels (ChV and ChI).

The components and method of operation of the system are described as follows.

3.1 ADC Measuring Head

The calibration system is based on an Analogue to Digital Converter (ADC). Various computer-based cards and units were tried for this purpose, however it was found that in general there were noise problems with these devices. Therefore, it was decided to construct a purpose built ADC measuring head isolated from the data processing computer.

The measuring head has 16-bit resolution and can operate at a maximum 100 kHz sampling frequency. It is powered by a highly isolated power supply unit [2]. Data exchange between the head and the computer is carried out using an optical-fibre [3]. The sampling clock signal is also sent via optical-fibre. Thus the head is fully isolated, the only point of electrical connection being the input terminals.

Signal conditioning consists of a differential input stage and anti-aliasing filter. The filter is based on a linear phase 7-pole Bessel response with -80db attenuation at 25 kHz. The filter is designed to have a stable and near-unity gain up to the maximum harmonic frequency of interest at 2 kHz.

The measuring head is calibrated over the required measurement frequency range using an electronic AC/DC measurement standard. This measurement is carried-out under computer control and corrections obtained which are automatically applied in subsequent measurements.

3.2 Waveform Generation

The IEC standard defines four classes of current wave shape named A, B, C and D. The maximum limits for these waveforms are given in the standard. In this measurement system, each wave class can be produced at either the limits or any proportion of the limits.

Generation is achieved using a commercial arbitrary waveform generator (ARB). Waveforms are sent via the IEEE bus to the ARB. The output voltage from the ARB, drives a transconductance amplifier to produce the current which is typically in the 1 to 5 A range. This current is then applied to a standard shunt resistor and to the device under test (DUT) current channel. With one terminal of the DUT at earth potential, the shunt will be at the voltage developed across the DUT, hence the need for the isolated and differential input ADC that samples the voltage developed across the shunt.

Currently the ARB has a 12-bit digital to analogue converter (DAC). It is hoped that this will be replaced by a higher resolution DAC for improved waveform definition

The sampling frequency for the measuring head is obtained by dividing the ARB sample clock and it is transmitted using an optical-fibre.

The voltage waveform in this phantom power system is assumed to be sinusoidal at 240 V, 50 Hz. This waveform is produced by a commercial calibrator. The calibrator is phase locked to the ARB using a synchronization pulse produced at the start of each current cycle. This pulse is sent using an optical-fibre in order that the voltage and current channels remain isolated.

Power factor control can be achieved by shifting the phase of the waveform samples that the computer sends to the ARB memory. This is carried-out using a constant group delay across all harmonics to maintain the wave shape. In general for non-sinusoidal waveforms, the relationship between the phase shift of the current waveform and the power factor is non- linear.

3.3 Standard Shunts

Sets of standard shunts are used to give current ranges of 1, 5 and 10 A. The are calibrated separately for DC value and for AC/DC resistance difference using bridge methods.

3.4 Measurement Procedure

For steady-state harmonics, with a given wave shape applied, both the measuring head and the DUT sample the current waveform for a given time, typically a minute. The NPL system over-samples and typically takes 512 samples per fundamental cycle. For these stationary (repetitive) waveforms, the samples are averaged in the time domain on a cycle by cycle basis to form a single cycle of data. The harmonic amplitudes and phase are then obtained by use of a FFT on this averaged data.

The FFT results are then used to correct the data sent to the ARB such that the amplitudes can be trimmed to the desired values for a given Class of wave shape. In this way, it is possible to set the harmonic amplitudes as defined in the standard to within about 100 $\mu\text{A/A}$ of fundamental. Any residual is subsequently corrected when processing the results. It is hoped that improved trimming can be achieved by use of a higher resolution DAC in the ARB.

By use of this procedure it is convenient to set the harmonics at the limits defined in the standard to check the pass/fail indication of the DUT for the given wave shape.

In the case of Class C and D wave shapes, the harmonic limits depend on measurements of the circuit power. In the case of class C, the power factor is used to define the 3rd harmonic limit. For Class D wave shapes the limits are given in mA/W. The ability of the DUT to measure power is assessed in a separate test against a calibrated wattmeter. For purposes of harmonic measurement and limit assessment, the DUT measurement of power is used to define the limits.

The type-B uncertainty for steady harmonic measurements using this system is estimated to be 100 $\mu\text{V/V}$ (95% confidence limits).

4. Fluctuating Harmonics

In many cases, a given load will be changing with time. For example, the changing torques on a motor, or the action of a "bang-bang" controller, will both cause the current drawn to vary in time. These changing loads can also give rise to harmonics that fluctuate in amplitude and phase.

Measuring waveforms made up of fluctuating harmonics using a Fourier Transform (FT) will in general give an erroneous result. This is because the FT is defined over infinite time and therefore has no resolution in time. For steady-state harmonics, a correctly configured FT calculation will use an integer number of cycles of the waveform, and assume it continues in a repetitive manor for infinite time. When the amplitude or phase is fluctuating this is not possible and the FT result is, in general, in error.

It is possible to apply the FT by breaking the signal up into short sequences and taking the FT of each. This windowing technique is often referred to as a Short Time Fourier Transform (STFT) and is recommended in the IEC standard for the analysis of Fluctuating Harmonics.

Even with the adaptations employed with the STFT the result of the analysis is still, in general, in error [4]. It is possible that in many cases that the resulting error is tolerably small, this is especially true if the fluctuation is slow. This does however present a problem as far as calibration of these instruments is concerned. For the analysis of one given signal the DUT may give a correct result, whilst with another it may have an error.

One solution is to use well-conditioned signals in the calibration laboratory, which can be measured with minimal error by the standard equipment. The result of the DUT can then be compared with a known quantity. The problem is that a given DUT may perform perfectly under these conditions but still give an erroneous result for other signals.

One such signal involves a burst of harmonic such that it takes on two distinct amplitudes. Analysis techniques have been developed to determine the harmonic amplitudes for this type of signal. By varying the burst time, and measuring the signal using standard equipment, the predicted response of the DUT can be computed and compared the actual response.

The modulation function which gives rise to the fluctuation is essentially arbitrary. The above method is only valid for well-defined laboratory signals. Current research into improved transform methods has the prospect of allowing more extensive calibration tests.

5. Conclusion

A calibration service using the methods described in this paper has recently been started by NPL. It is hoped that these services will at least help to reduce some of the accuracy problems that may currently exist with power analyser equipment.

The calibration also covers assessment of Flickermeters used in IEC 1000-3-3:1994. These tests are made at the recommended specifications for Flicker meter Classifier defined in Table 3 of IEC868-0:1991.

The problems with Fluctuating Harmonics mean that these tests will continue to evolve as research gives rise to improved methods. It is also possible that some of the techniques currently under development will eventually become the basis for improved commercially available devices.

6. References

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 - [3] Robinson I A: "An optical-fibre ring interface bus for precise electrical measurements", Measurements Science Technology 2 (1991) 949-956, 1991.
 - [4] Wright P.S., "Short Time Fourier Transforms And Other Transforms Applied To The Calibration Of Power Analysers", CPEM Conference Digest, July 1998.