초정밀 고조파 측정을 위한 디지털멀티미터기의 사용

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Use of DMMs for High Precision Harmonics Measurements

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Abstract - In this study, the method for the measurement of harmonics at nonsinusodial signal, which utilizes two synchronized high precision digital multimeters has been developed. The harmonics of voltage and current waveforms were computed from the acquired digitize samples through the DMMs and using developed software which based on FFT algorithm. The system can be used as a reference system to calibrate harmonic analyzers.

1. INTRODUCTION

With the progress of Industries, power electronics equipment is widely use in power measurement system. The nonlinear characteristics of these equipment and power lines produce sirius hormonic pollutions which is caused to bad quality of power. Several types of power analysers designed for accurate measurement of current and voltage harmonics are available commercially. These power analysers are used by industries for harmonics measurements, which are requiring traceable calibration by National Metrology Institutes (NMI). Therefore, harmonic menacement capabilities has grown and the demands on NMI to provide calibration facilities and traceability for such measurements has increased.

Dual channel sampling technique is applied whenever to electrical parameters are sampled, in the case of voltage and current, for the measurement of power, harmonics, phase angle etc. The precision of a sampling method mainly depend on the choice of the analog to digital converters (ADC). Fast ADCs have a resolution which is generally less thea 16 bits. High resolution ADCs, on the other hand, have a non negligible data aquisition time and, when they are used for the measurement of an ac voltage, the variation of the signal during the aquisition time is grater than the resolution. So an aquisition system that utilizes these converters needs an additional sample and hold circuit, which can then introduced its own symmetric errors. In order to avoid difficulties of those approaches, a method employing high precision Digital Millimeters (DMMs) can be used since some DMMs have advance futures and high quality integrating A/D converters with an IEEE-488.2 interface to control a process externally.

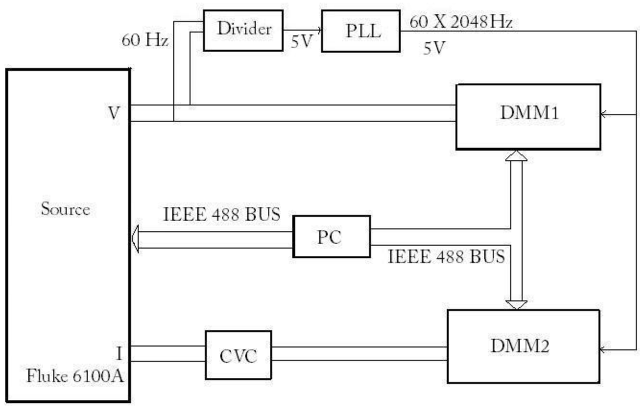
In this study a highly accurate digital sampling system with sophisticated software algorithm has been assembled and the system analyses the fundamental and its 50^{th} harmonics of the nonsinusoidal waveform.

2. Theory

2.1 Layout

The basic circuit of system is shown in Figure 1 and its consist of two sub systems. One is for generation of the voltage and current. The other one is data aquisition system to measure the waveform.

The source of the system is Fluke 6100A, Electrical power standard that supplies voltage and current waveforms at the same frequency, variable in amplitudes and with phase difference that can be adjusted 0 to 2π. The aquisition system consists of two identical high precision digital voltmetes (Agilent 3458A) used as integrated analog- to-digital converters. One of the two DMMs is applied directly for the aquisition of the voltage signal, while the other, connected to a current-to-voltage converter (CVC), is utilized for the aquisition of the current signal. The CVC is consist of current shunt with an amplifier connected at its output. Both DMMs are connected to the computer via GPIB and controled by the software.
The PLL circuit synchronize dual channels with the running frequency of 2048*60 Hz.



<Fig. 1> layout of the measuring circuit

2.2 Calculation of Harmonics and RMS values

In digital signal processing periodical signal includes integrating over a cycle or an integrate number of cycles of the signal. Let N sampled data $x_0, x_{1,} x_{2,} \cdots\cdots\cdots\cdots x_{N-1}$ are acquired, the rms values of the signal X is given by

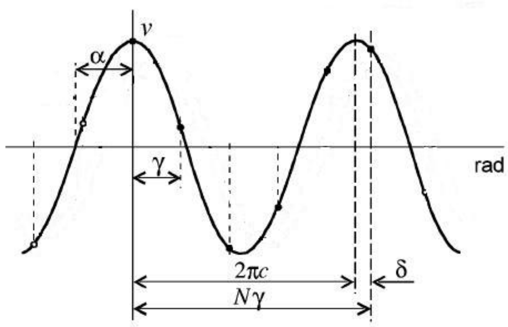
$$X_{rms} = \left(\frac{1}{N} \sum_{i=0}^{N-1} x_i^2 \right)^{\frac{1}{2}} \qquad (1)$$

Considering the discrete signal waveform can be represent as shown in Figure 2, where only one single cycle is indicated and parameters are explain in terms of the phase angles. In Fig. 2,α is the initial phase angle of the waveform. The phase difference between samples is γ and can be represent as in equation (2).

$$\gamma = wT_s = 2\pi \frac{f}{f_s} \qquad (2)$$

where T_s is the sample time. The f_s and f are sample frequency and signal frequency respectively. Similarly initial phase angle α can be written as

$$\alpha = wT_i \qquad (3)$$



<Fig. 2> Single channel sampling

Equation (1) can be used to calculate rms values over a summation period Nγ. In real situation, the summation interval of equally spaced samples should be equal to an integer number of periods of a periodic voltage and current signal

$$N\gamma = 2\pi c \qquad (4)$$

However, equality (4) is not fulfill perfectly and introduce difference called truncation angle error δ

$$\delta = 2\pi c - N\gamma \qquad (5)$$

The truncation error of voltage or current when calculate the rms values is

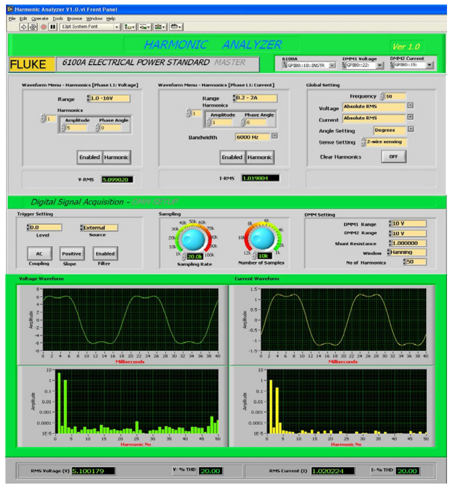
$$\epsilon = \frac{1}{2N} \frac{Sin\delta}{Sin 2\pi \frac{f}{f_s}} Cos\left(2wT_i - \delta - 2\pi \frac{f}{f_s}\right) \qquad (6)$$

Minimizing truncation error we can obtain accurate results. Therefore, sampling parameters should be chosen to fulfill equation (5) as much as possible. Furthermore, it is advantages to increase the number of samples 'N'. In Digital Signal Processing, the ratio of f_s to f should be more than two to avoid the aliasing according to the Nyquist criteria.

The voltage measured across the current shunt and direct supply are digitised by the digital multimeters and 10 k samples can be stored in the multimeter before sending the samples to a PC over the GPIB. Then the software calculate angle error, initial time and truncation error to correct the rms value of the signal.

2.3 Software

The harmonics calibration software is developed using LabView. The control functions of the system such as number of samples , sampling rate, are set before run the programme. FFT algorithm calculate compleat harmonic analysis for the first 50 harmonics and their peak frequencies and total harmonics distortions. Figure 3 shows a screen printout of the computer based harmonic calibration system software.



<Fig. 3> Screen printout of the power calibration software.

3. Results

The software was tested giving voltage and current waveforms to DMM. The software was calculated each harmonic amplitudes and rms values of current and voltage nonsinusodial waveforms. The test results are shown in Table 1.

<Table 1> Results of the harmonics measurement

Har. no.	App. Value	PA Mea.	Sys Mea.
1	4.0 V	3.99957 V	3.99927 V
3	1.0 V	0.99990 V	0.99983 V
5	0.5 V	0.49990 V	0.49988 V
7	0.1 V	0.09997 V	0.10000 V
9	0.1 V	0.09998 V	0.09999 V
2,4,6..	0.0 V	0.00003 V	0.00002 V
1	0.8 A	0.79990 A	0.80005 A
3	0.2 A	0.19995 A	0.20005 A
5	0.1 A	0.10000 A	0.10000 A
2,4,6..	0.0 A	0.00005 A	0.00004 A
RMS Voltage		4.15495 V	4.154964 V
RMS Current		0.83074 A	0.830831 A
THD Voltage		28.17	28.17
THD Current		27.95	27.96

Conclusion

The main purpose of the harmonics analysing system is to analyse the harmonics in nonsinusodil waveforms and maintained as reference to calibrate commercial harmonic analyzers. The thermal transfer standard is going to use to validate and fine the accuracy of the system. Furthermore, the software is more flexible and many reference quantities can be calculated particularly those need for harmonics measurements. Further work is planed to improve the accuracy using of discrete fourier transform algorithm.

Reference

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