References to scientific publications

Power Measurement Techniques for Nonsinusoidal Conditions. The Significance of Harmonics for the Measurement of Power and other AC quantities
S. Svensson
Doctoral thesis 1999, Chalmers University of Technology
http://publications.lib.chalmers.se/cpl/record/index.xsql?pubid=921
Abstract: The increased application of power electronics and other non-linear loads makes it necessary to re-evaluate the measuring techniques used in the power system, and the measuring problems these loads cause. An instrument utilising digital sampling techniques has been built and evaluated at the Swedish National Testing and Research Institute (SP). The Digital Sampling Watt Meter (DSWM) is based on standard laboratory equipment: digital multimeters, voltage dividers, shunt resistors and a PC. The DSWM is versatile and can be used for calibrations of many quantities. The most basic ones are the (total) active power and the amplitude and phase angle of individual harmonics of non-sinusoidal voltages and currents.
The DSWM was first verified for sinusoidal signals. At 120 V and 5 A and power factor one, the DSWM has an estimated uncertainty (2s) of 60 ppm at 50 Hz and 600 ppm at 20 kHz. The wattmeter has also participated in three international comparison with satisfactory results. The most important additional feature, the input distortion, has been verified to be less than 800 ppm for all harmonics and lower than 100 ppm for most harmonics.

Some AC quantities, as the reactive power, are not properly defined for non-sinusoidal situations. Efforts are made in this work to understand and explain the problems of extending the reactive power definition to cover non-sinusoidal situations. The main conclusion is that reactive power is used to obtain information on more than one property of the power transmission mechanism, e. g. phase angle, transmission efficiency and line voltage drop. No single power definition can alone provide information on all these properties in a non-sinusoidal situation. Moreover, instrument designs may not comply with any of the extended definitions and these meters exhibit extra errors due to this non-compliance in non-sinusoidal situations.

Some conclusions on future demands on energy meters can be drawn, based on the error analysis of these meters and an analysis on how the responsibility for the harmonic currents and voltages in the power system can be determined and shared. One conclusion is that it is not possible to make a precise determination of the responsibility for harmonics based on any power measurement alone.

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Improved Model and Phase-Angle Verification of Current Shunts for AC And Power Measurements
S. Svensson; K.-E. Rydler; V. Tarasso
Precision Electromagnetic Measurements Digest, 2004 Conference on Precision Electromagnetic Measurement (CPEM), http://icpem.org/
Volume , Issue , June 2004 Page(s):82 - 83
Digital Object Identifier 10.1109/CPEM.2004.305451

Summary: The phase angle error of the output voltage of resistive shunts may depend on a number of stray impedance components. These components have been estimated for some shunt designs. Their total contribution has been measured by a LCR meter method and compared to a step-up procedure. The agreement between the different methods, for measureme nt of phase angle difference of two shunts, was within a few murad at 1500 Hz

Voltage dividers with low phase angle errors for a wideband power measuring system
Rydler, K.-E.; Svensson, S.; Tarasso, V.
Precision Electromagnetic Measurements, 2002. Conference Digest 2002 Conference on Precision Electromagnetic Measurement (CPEM), http://icpem.org/
Volume , Issue , 2002 Page(s): 382 - 383
Digital Object Identifier 10.1109/CPEM.2002.1034882

Summary:A set of resistive voltage dividers has been designed for low phase angle errors. The dividers were made for a wideband power measuring systems to cover voltages up to 1000 V. The phase angle errors of the dividers have been verified in a step-up procedure using two sampling voltmeters. Except for the highest ranges the phase angle errors are within a few µrad at 50 Hz and within ± 50 µrad at 1500 Hz

A watt meter standard for the audio frequency range
Svensson, S.;
Precision Electromagnetic Measurements Digest, 1998 Conference on Precision Electromagnetic Measurement (CPEM), http://icpem.org/
6-10 July 1998 Page(s):546 - 547
Digital Object Identifier 10.1109/CPEM.1998.700048

Summary: A watt meter standard, based on digital sampling, has been designed and evaluated for the audio frequency range. The watt meter is based on two commercially available sampling DVMs. The power spectrum is calculated with DFT analysis. High accuracy is.....

Verification of a calibration system for power quality instruments
Svensson, S.;
Instrumentation and Measurement Technology Conference, 1998. IMTC/98. Conference Proceedings. IEEE. http://www.ewh.ieee.org/soc/im/imtc/

Volume 2, 18-21 May 1998 Page(s):1271 - 1275 vol.2
Digital Object Identifier 10.1109/IMTC.1998.676931

Summary: A versatile calibration system that is suitable for calibrations of power quality instruments has been built at Swedish National Testing and Research Institute. The instruments to be calibrated are intended for measurements under nonsinusoidal conditions …