YOKOGAWA EUROPE SAMPLING WATTMETER FOR LOW FREQUENCIES

Erik Kroon

European Standards Laboratory Yokogawa Europe Solutions B.V.

Euroweg 2, 3825 HD Amersfoort, The Netherlands

erik.kroon@nl.yokogawa.com

Abstract

A high accuracy power measurement system, based on digital sampling techniques, is being developed at the standards laboratory of Yokogawa in Europe. The system is based on two sampling voltmeters and a synchronization device. Using potential transformers and compensated current transformers with an AC shunt resistor, the uncertainty is less than 20 ppm for active, reactive and apparent power for frequencies between 45 Hz – 60 Hz.

Introduction

The request for lower uncertainties in power measurements are increasing, especially in the transformer industries. Their role is to ensure that the electricity is distributed in an efficient and reliable way. As a result, manufacturers are constantly looking to develop transformers that are more economical as well as more ecologically friendly. The key to meet these demands is the reduction of losses and costs at all stages of the development cycle. For the manufacturer to build a reliable transformer, it is necessary to measure losses accurately. This is only possible when the measurement system is calibrated at the highest level.

Sampling Wattmeter

The core of this set-up is formed by two sampling voltmeters that simultaneously sample the voltage and current signal. From these data a computer subsequently calculates the power. An overview of the set-up is schematically depicted in figure 1. The set-up essentially consists of two parts: one for generation and one for the measurement of the power, where the latter is the core of the system. The incorporation in the system of the power source is needed to feed the standard and the Device Under Test (DUT) was crucial for avoiding problems with synchronization of the voltmeters.

Generator

The generator used in our set-up is a commercial Clarke-Hess 5000 phase standard. The signals are amplified with a modified Yokogawa 2558 AC Voltage Standard to get the test voltage and a Fluke 5220A transconductance amplifier to make the test currents. The resulting signals are then fed to the DUT and the standard via two isolation transformers to avoid any dc levels on the test signals. The Clarke-Hess 5000 is modified to take out synchronization signals needed for the voltmeters.

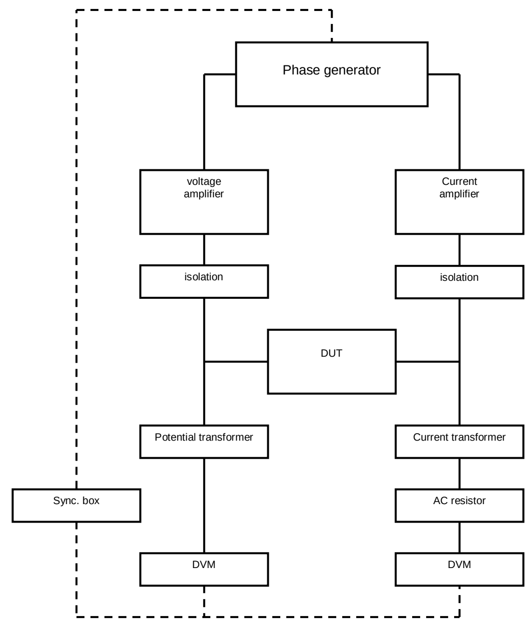

Figure 1. Schematic overview of the sampling wattmeter set-up at Yokogawa Europe.

Transformers

For measurement of the voltage signal a two stage transformer is used. The test voltage is transformed to 0.8 V level. The test current is transformed to 8 mA with an electronically compensated current transformer. This 8 mA is subsequently converted to 0.8 V with a Vishay thin film type resistor with negligible ac error. The fact that both voltmeters are used at the same, 0.8 V level is one of the great strengths of the system. The meters have the same input band wide and signal delay, also the meters can be exchanged, which greatly facilitates the search for systematic errors in the set-up.

Voltmeters

The sampling of the voltage and current signal is performed by two Agilent 3458A digital voltmeters in their 1 V ranges. The voltmeters are used in the dc mode with a nominal aperture time of 22 μs in order to reduce the effect of the dead time, especially significant at smaller apertures. Each measurement consists of taking 512 samples per period during 18 periods before the data is transported to the computer over the communication bus for further calculations. A nominal test frequency of 52.941 Hz is used so that 18 periods of measurements exactly coincide with 17 periods of the 50 Hz net, which greatly reduces the influence of mains interference signals. For exact measurement of the power, it is important that samples are taken over an exact number of periods of the signal. For this reason, the Clarke-Hess generator was modified so that extra signals are linked to the synchronization electronics to trigger the voltage and current meters simultaneously.

Software

The system is completely computer controlled using software. The data from the meters are saved in arrays and with the standard formulas of the software all needed parameters are calculated. On the screen the shapes of the waveforms and the calculated phase angle are shown, as well as the individual results, the mean and the standard deviation of the different measurements.

The software removes any dc offsets before the power and phase angle calculations are preformed. These offsets mainly originate from the voltmeters, since the fast sampling does not allow for correction for the offsets in the meter during the measurement process. The removal of the dc offsets particularly affects the phase angle measurement: the resolution is in the level of μdegrees.

Voltage Measurement

From 8 Volt up to 300 Volt a two stage transformers are used to transform the input voltage to a lower voltage level while the phase measurement is very accurate. Because the phase measurement is excellent the system is able to measure power factors down to 0.0001. For lower voltage (1 to 8 Volts) and higher voltages (300 to 800 Volts) the direct input of the voltmeter is used. But this limits the power factor to be measured only at PF = 1.

Current Measurement

For low currents (1 to 10 mA) an AC shunt is used to convert the current to a voltage. For others currents from 10 mA up to 1200 A electronics compensated transformers are used combined with an AC resistor. The system capability for power is from 0.1 mW to 960 kW using the phantom method.

Traceability

The traceability of the power calibration system is to Voltage, resistance and Phase. The voltmeters are calibrated using DC Voltage standards. During the DC Voltage calibration the same sampling mode is used as the AC voltage signal. But when applying an AC signal we have to correct for the low pass filter effect of the 22 μs aperture time. Also the analog band wide is taken into account. The transformers are calibrated on the ratio and phase angle, using the power calibration system as a ratio calibration system. The high current transformer is externally calibrated at an accredited laboratory. The AC resistors are compared using DC resistors and the relative AC/DC behavior.

Conclusions

We have significantly improved the uncertainty of the standard wattmeter set-up at the European Standards Laboratory in Amersfoort. A bilateral comparison with VSL (Dutch National Standards Laboratory) shows an uncertainty of less 20 ppm on 100 V and 1 A & 5 A range using power factors from 1 to 0.001.

Our capability @ 53 Hz:

Voltage 0.1 V to 800 V
Current 1 mA to 1200 A
Power 0.1 mW to 960 kW
Cos (φ) 0.0000 to 1.0000 (inductive or capacitive)

Uncertainty:

From 0.0013 % to 0.014 % W/VA
Multiplied by a coverage factor $k = 2$, which for normal distribution corresponds to a coverage probability of approximately 95%. The standard uncertainty of measurement has been determined in accordance with the EA4/02