A Calibration System for Current Transducers up to 100 kHz

Erik Kroon

Yokogawa Europe Solutions B.V.
erik.kroon@yokogawa.com

***Abstract* — Modern power electronics used in motor drives and inverters produce complex current waveforms with higher frequency components, Current Transducers are able to measure these fast signals; however, most calibrations laboratories of the current transducers are limited to 50, 60 Hz region. The ratio and phase traceability for higher frequencies is difficult to obtain; however, it is required for efficiency determination. The European Standards Laboratory of Yokogawa Europe Solutions has developed a system for calibrating Current Transducers up to 100 kHz and 100 A. Three commercially available Current Transducers have been calibrated using this system. The calibration system and results are explained in this paper.**

***Index Terms* — Calibration, Current measurement, Current transformers, Measurement, Phase measurement.**

I. Introduction

Power meters of Yokogawa have a wide bandwidth, therefore the Yokogawa European Standard Laboratory in the Netherlands are able to offer power traceability up to 100 kHz [1]. The current input of these power meters is limited to 30 or 50 A. To extend the current, Current Transducers (CT) are used. The most used manufacturers are Danisense, PM Special Measuring Systems and Signaltec. From these manufacturers a DT100ID, DS600ID, MACC 2 Plus, CT 500 and a CT 1000 were calibrated on the Current Transducer Calibration System, developed by the Yokogawa European Standards Laboratory to offer traceability up to 100 kHz and 100 A.

II. Current Transducer Calibration System

The Yokogawa Current Transducer Calibration System consists of a transconductance amplifier to generate a current, the current is applied to a coaxial chamber which contains the CT under test. From the coaxial chamber, the current will flow through a high current coaxial shunt which is used as reference to determine the primary current. The secondary current from the CT is connected to a wideband shunt to convert the current to a voltage. The voltage of the high current coaxial shunt and the voltage of the wideband shunt are measured by a Fluke 5790B AC Measurement Standard to determine the ratio of the current transducer. The AC Measurement Standard is then replaced by a Yokogawa WT5000 Precision Power Analyzer to measure the phase deviation of the current transducer. Due to the limited compliance voltage of the transconductance amplifier, the maximum current that can be generated is 100 A up to 60 kHz and sloped down to 60 A at 100 kHz. By using two turns on the CT it is possible to simulate a current of 200 A up to 40 kHz and down to 90 A at 100 kHz. These amplitudes are achieved by using coaxial chamber, which reduces the required compliance voltage compared with a direct connection. The coaxial chamber provides a well-defined and uniform electric field distribution.

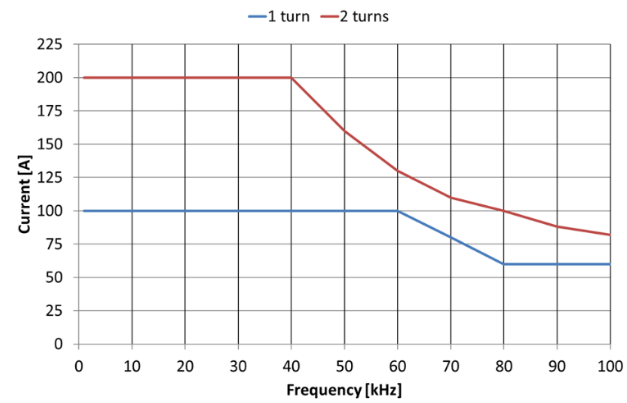

Fig. 1. Current amplitude Capability of the Calibration Transducer System.

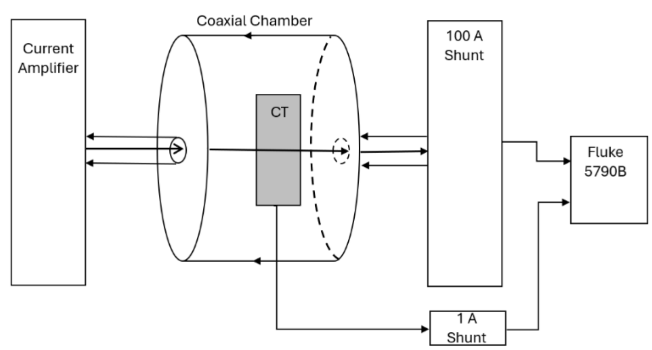

Fig. 2. Calibration Transducer System setup for ratio measurement.

III. Calibration of Current Transducers

A. Linearity of Current Transducers

As it is not able to reach the desired 100 A at 100 kHz, the effect of linearity at higher frequencies was measured. This was done for Currents of 40, 60 A up to 100 kHz and 80, 100 A up to 60 kHz. The results of these measurements show that the effect is 0.032 % at 100 kHz and <0.002 % at frequencies lower than 60 kHz in ratio. This effect is added to the uncertainty budget. This enables extrapolation of the ratio values up to 100 A and 100 kHz.

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B. Reference 100 A Shunt

The 100 A shunt was developed based on the design of Justervesenet [2]. It has an impedance of 7.5 mΩ. It was calibrated for AC/DC difference and DC resistance. Up to 10 kHz the AC/DC difference is < 2 ppm increasing to 109 ppm at 100 kHz. The power coefficient was characterized and is < 50 ppm at 100 A while dissipating 75 W. The phase deviation was compared with a known current shunt.

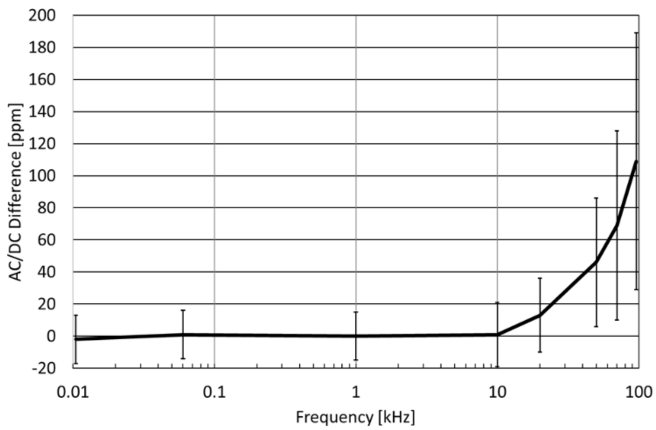

Fig. 3. AC/DC Difference of 100 A Shunt.

C. Calibration of Ratio

To define the ratio of the CT the output voltages of the shunts are measured by the Fluke 5790B AC Voltage standard. The DC resistance and AC/DC different values are set into the Fluke 5790B to correct for the impedance of the shunts. The voltage readings are used to calculate the ratio deviation of the CT.

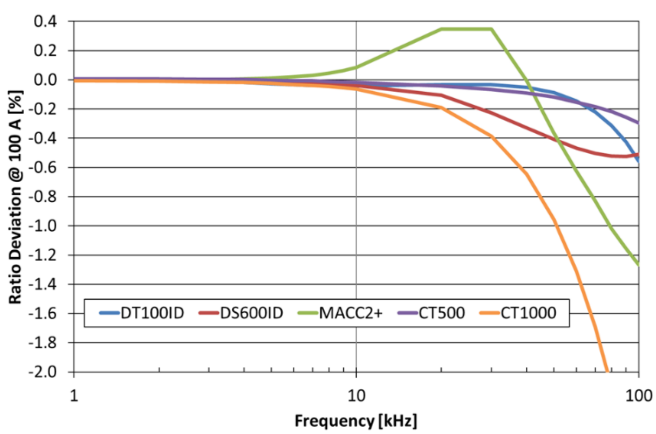

Fig. 4. Ratio deviation of Current Transducers (no error bars included).

As frequency has no significant effect on the ratio of the CT below 1 kHz, the calibration and evaluation in fig 4 starts at 1 kHz. Fig. 4 shows that frequency effects the ratio from 3 kHz. CTs, with a higher nominal current, tend to have a smaller bandwidth which is reflected in the results of the ratio measurements. The relative uncertainty for calibration of the ratio starts from 0.007 % at 40 Hz and increases to 0.035 % at 100 kHz at 100 A.

D. Calibration of Phase deviation

To calibrate the phase deviation of the CT, the Fluke 5790B is replaced by a Yokogawa WT5000 Precision Power Analyzer as a phase meter. Corrections were applied for the phase deviation of the reference shunt and the Yokogawa WT5000. The current transducers were measured at a current of 60 A, starting from 1 kHz in fig 5. Above the 10 kHz, the frequency starts to influence the phase deviation of the current transducers. The uncertainty starts from 87 µrad at 40 Hz to 8.7 mrad at 100 kHz.

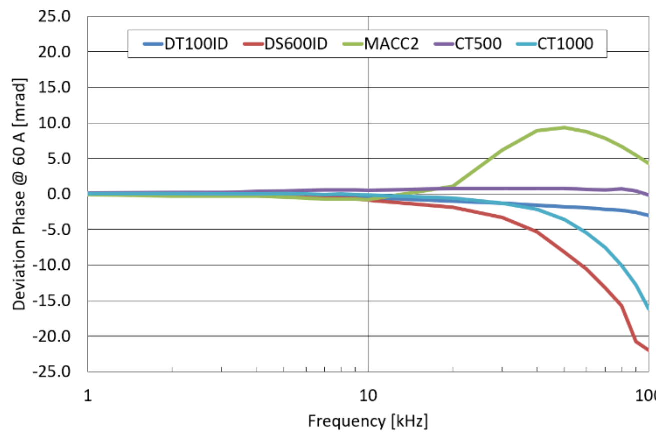

Fig. 5. Phase deviation of the current transducers. (no error bars included)

VI. Conclusion

By using the newly developed Calibration System for Current Transducers, it is possible to characterize the ratio and phase performance of Current Transducers up to 100 kHz and 100 A. By using two turns, 200 A up to 40 kHz can be achieved, with increased uncertainty. This new calibration system demonstrates the performance of Current transducers, when using them to measure distorted waveforms i.e. beyond the limited bandwidth of 50, 60 Hz from traditional calibration systems.

References

[1] E. Kroon, “Bilateral Comparison LF Power up to 100 kHz”, *2016 Conference on Precision Electromagnetic Measurements (CPEM 2018)*, Paris, 2018, pp. 1-2.

[2] Lind, K.; Sørsdal, T.; Slinde, H.; ”Design, Modeling, and Verification of High-Performance AC–DC Current Shunts From Inexpensive Components” *IEEE Transactions on Instrumentation and Measurement*, Volume: 57 , No. 1, 2008, pp 176 – 181