XVIII IMEKO WORLD CONGRESS
Metrology for a Sustainable Development
September, 17 – 22, 2006, Rio de Janeiro, Brazil

CURRENT TRANSFORMER USAGE FOR NONHARMONIC PERIODIC CURRENTS

Jan Hlaváček [1], *Karel Draxler* [2], *Radek Procházka* [3]

[1] FEE CTU in Prague, Department of Power Eng., Prague, Czech Republic, xhlavace@fel.cvut.cz
[2] FEE CTU in Prague, Department of Measurement, Prague, Czech Republic, draxler@fel.cvut.cz
[3] FEE CTU in Prague, Department of Power Eng., Prague, Czech Republic, xprocha3@fel.cvut.cz

Abstract: This paper deals with composite error determination of current transformers (CT) for purpose of nonharmonic periodic current measurements. The experiment was performed for typical nonharmonic periodic waveforms that occur in power grids with frequency 50 Hz. The area of measurements was extended also for higher fundamental frequency values.

Keywords: current transformer, nonharmonic current, composite error.

1. INTRODUCTION

The main application field of CT is the high harmonic current measurement in power grids. In this case the are defined its errors, ie. current error and phase displacement. Sometimes it is necessary to use CT for nonharmonic periodic currents with zero DC component. These currents arise in rectifier feeding circuits and other circuits with controlled semiconductor switching elements. In that case the CT ratio accuracy is given by composite error ε_C, defined by this expression

$$\varepsilon_C = \frac{100}{I_P}\sqrt{\frac{1}{T}\int_0^T \left(K_n i_S - i_P\right)^2 dt} \tag{1}$$

where K_n is CT rated ratio, i_P is primary current actual value, i_S is secondary current actual value, I_P is primary current effective value and T is one cycle period.

There is described measurement of the composite error for some typical nonharmonic periodic current waveforms that come into question in electroenergetic systems.

There are described methods of the composite error evaluation, including some measurement results. There were measured periodic nonharmonic waveforms whose harmonic components form wider frequency spectrum. The composite error depended on the CT behavior in wider frequency spectrum of harmonic frequency currents.

2. CT APPLICATION IN WIDER FREQUENCY RANGE OF HARMONIC CURRENTS

During the current measurement with a CT in wider frequency range of harmonic currents apply magnetic core properties and parasitic capacitances of the winding. Influence of these capacitances is represented by a capacitance C_p in the substitute circuit, see Fig. 1. The error frequency dependence is given by no-load current I_0, by the assumption that the CT load is real and the secondary winding leakage inductance is negligible. The I_0 amplitude is corresponding to the voltage U_i on the secondary winding rated burden given as

$$U_i = \left(R_z + R_2\right) I_2 \ , \tag{2}$$

where R_{BZ} is resistance of burden, R_2 is DC resistance of secondary winding.

Providing that the CT real burden and the secondary current are constant, then the voltage U_i is constant in whole frequency range. The error frequency dependence character corresponds to the frequency dependence character of I_0. The I_0 dependence is for the transformer TL20 with the real burden 5 VA and for the transformer CLA1.3S with the real burden 30 VA is in Fig. 2. Parasitic capacitance C_p together with inductance L_m form a resonant circuit. It is assumed

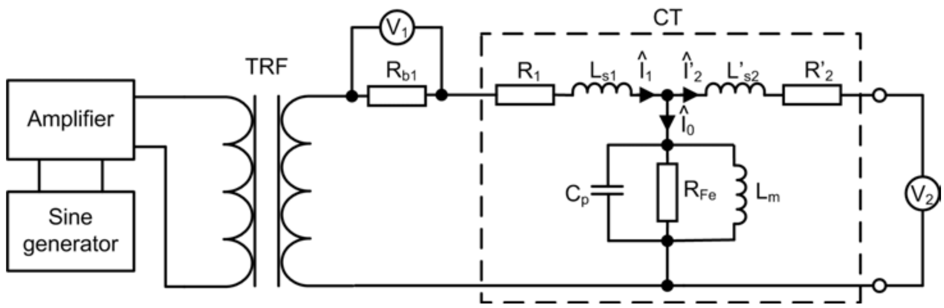

Fig. 1. CT substitution diagram

that current errors increase above the resonant frequency. Detailed analysis of this effect is described in [1].

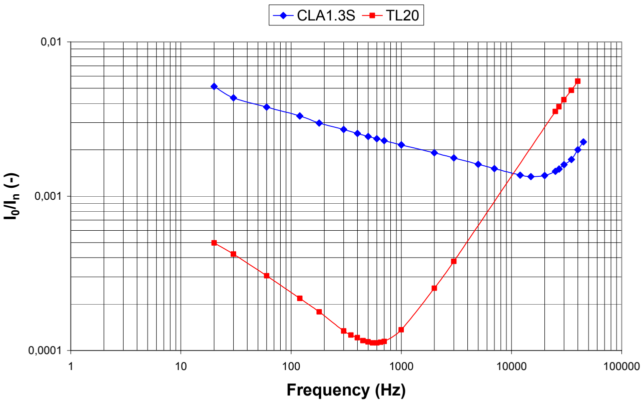

Fig. 2. No-load current frequency dependence character

3. TYPICAL NONHARMONIC PERIODIC CURRENT WAVEFORMS

There were chosen some typical current waveforms for CT composite error measurements. The first one is the input current of the one-phase bridge rectifier, see Fig. 3. And the second one is the three-phase controlled six-pulse rectifier, see Fig. 4. There was also chosen an experimental impulse current waveform, see Fig. 5, that contains wide range of frequencies. These waveforms were stored into the arbitrary generator.

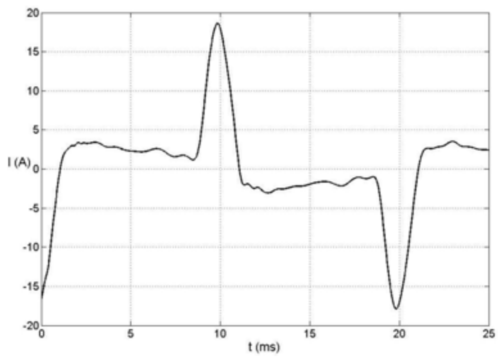

Fig. 3. One-phase bridge rectifier input current

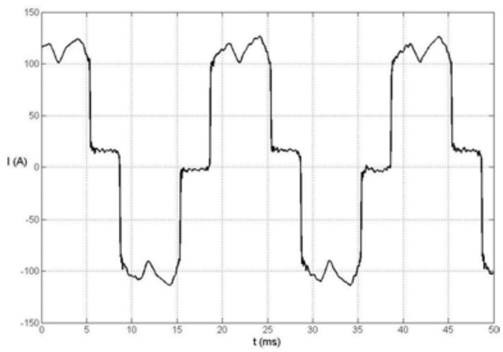

Fig. 4. Three-phase six-pulse rectifier input current

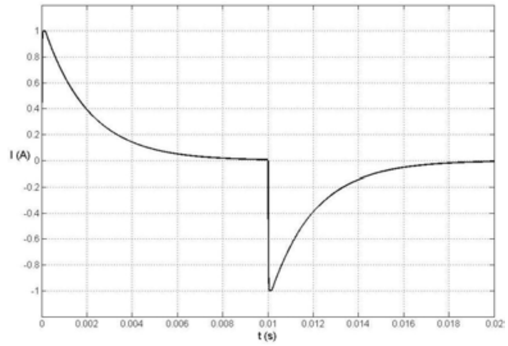

Fig. 5. Experimental impulse current waveform

4. MEASUREMENT OF COMPOSITE ERROR

4.1. Composite error measurement for transformation ratio 1:1

The composite error measurement was performed for CT ratio 5 A/5 A, see Fig. 6. The error was measured on the laboratory CT, type TL20, made by Metra Brno, class 0.05; rated burden 5 VA real.

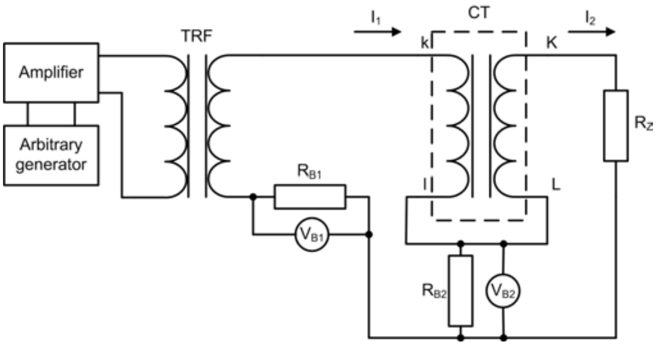

Fig. 6. Measurement layout for the CT transformation ratio 1:1

The difference of primary and secondary currents I_1 and I_2 was measured using a 1 Ω coaxial shunt. The primary current I_1 was measured by means of a 0.1 Ω coaxial shunt. The RMS voltage on shunts was measurered by multimeters Agilent 34401A. Selected current waveforms were generated by arbitrary function generator Agilent 33250A. Its output voltage was led into the power amplifier Goertz, which supplied the isolation transformer TRF, see Fig. 6. The measurement was performed for 50 % of the primary rated current I_{1R} and for the impulse fundamental frequency range 50 Hz up to 1 kHz.

The composite error was practically calculated from formula (3) that was derived from expression (1).

$$\varepsilon_C = \frac{100}{I_P} \cdot \frac{V_{B2}}{R_{B2}} = 100 \cdot \frac{V_{B2}}{R_{B2}} \cdot \frac{R_{B1}}{V_{B1}} \quad , \qquad (3)$$

where R_{B1}, R_{B2} are shunt resistances and V_{B1}, V_{B2} are effective voltages measured on these resistors.

Composite error dependences on impulse fundamental frequencies are shown on Fig. 7.

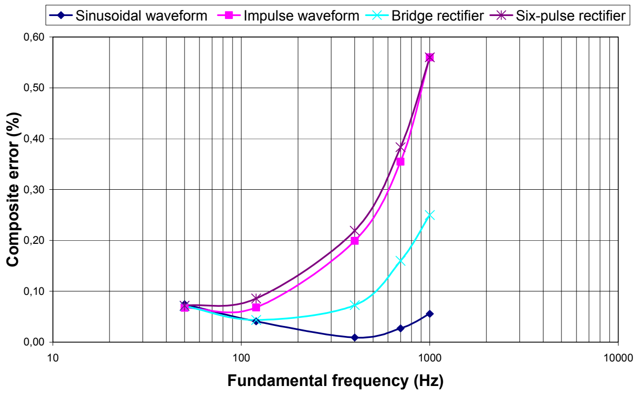

Fig. 7. Composite error versus frequency of the CT, type TL20

4.2. Composite error measurement by means of two shunts with resistance ratio equal to CT transformation ratio

The measurement of composite error can be also performed with two shunts, one placed in the primary side of CT and one in the secondary side of CT, which have the resistance values with the rate equal to the CT transformation ratio. Shunt voltage terminals are connected in phase opposition, see Fig. 8. The effective value of difference of shunt voltages is measured by a precise multimeter Agilent 3454A. Determined composite error for CT CLA1.3S, 10 A/1 A (class 0.5, rated real burden 30 VA) for fundamental frequency range 50 Hz – 5 kHz and for rated burden is shown in Fig. 9.

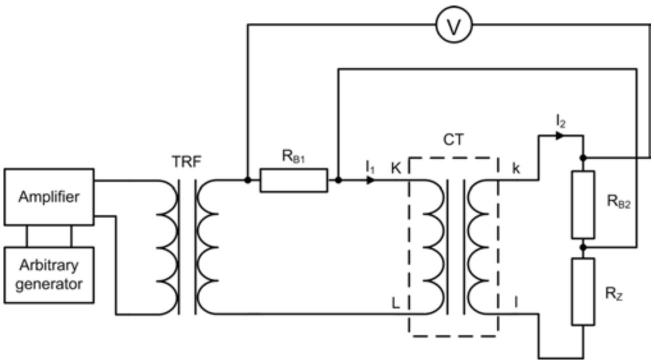

Fig. 8. Measurement circuit layout for measurement with shunts ratio equal to CT transformation ratio

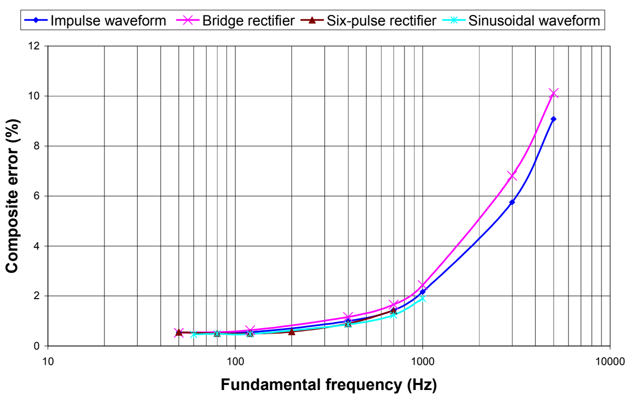

Fig. 9. Composite error for the CT type CLA1.3S

4.3. Composite error measurement by two shunts for common CT ratio

For the common CT ratio is the only way how to determine the composite error by means of two shunts, see Fig. 10. Voltage drops on these shunts may be proceeded by an A/D converter. Sampled voltage waveforms on shunts R_{B1}, R_{B2} are stored into files and then processed in a PC.

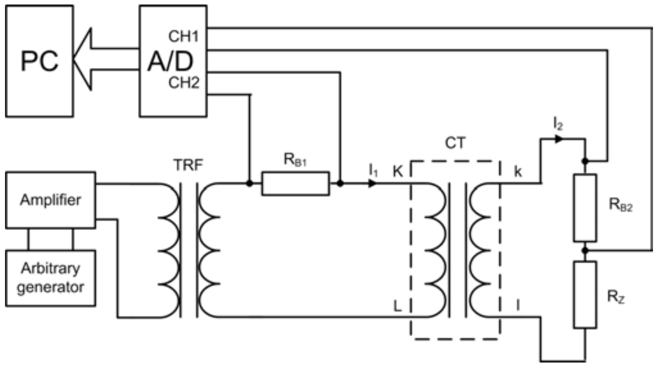

Fig. 10 Layout for measurement by means of two shunts for common CT ratio

Obtained waveforms are denoised, converted to currents and the composite error is numerically computed according to equation (1). Fig. 11 shows the frequency dependence of composite error for CT CLA1.3S loaded by rated burden 30 VA.

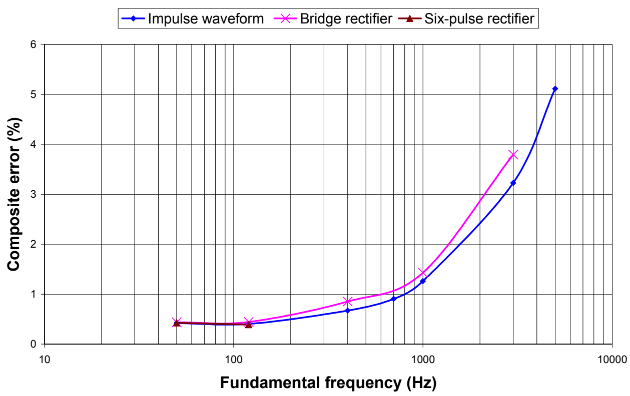

Fig. 11. Composite error for the CT type CLA1.3S

5. CONCLUSION

There were described composite error measurement fundamental methods for nonharmonic periodic current waveforms without DC component. Estimation of the composite error is realizable experimentally only by reason that the CT is non-linear circuit. Three methods for composite error measurement were used

- for the CT ratio 1:1
- by means of two shunts with resistance ratio equal to CT transformation ratio
- by means of two shunts for common CT ratio

Differential method should be used for the best measurement accuracy. This method is optimal for the ratio 1:1, see Fig. 6. In common cases of other CT ratios the disadvantage is the need of standard shunts usage with their resistance ratio equal to CT transformation ratio, see Fig. 8. The universal method with two shunts for common CT ratio is usable for transformers with accuracy class 0.5 %. In case of lower accuracy class there is high measurement uncertainty due to measurement of two proximate voltages. There may apply interference voltages, noise, etc.

The composite error at frequency 50 Hz in case of applied nonharmonic periodic waveforms is almost the same as in case of the sine waveform. Great increase of the composite error comes when the nonharmonic waveform of fundamental frequency overruns hundreds of Hz.

ACKNOWLEDGMENTS

The work was supported by the research program No. MSM6840770015 "Research of Methods and Systems for Measurement of Physical Quantities and Measured Data Processing" of the CTU in Prague sponsored by the Ministry of Education, Youth and Sports of the Czech Republic.

REFERENCES

[1] K. Draxler, R. Styblíková, “Use of Instrument Current Transformer in Wider Frequency Range” Proc. of IMECO World Congress 1999, Vol.6., pp.1-5.

[2] Current Transformers, International Standard IEC 185.

[3] K. Draxler, R. Styblíková, “Use of nanocrystalline materials for current transformer construction”, JMM (Journal of Magnetic Materials) 157/158 (1996), pp.147-148.