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Measurements of current error and phase displacement of the CT in condition of distorted currents transformation

Abstract. *The aim of the research is to determinate the influence of sinusoidal conductive disturbances on current error and phase displacement of the CT with Ni80Fe20 toroidal core.*

Streszczenie. *Celem badań jest określenie wpływu sinusoidalnych zaburzeń przewodzonych na wartości błędów prądowego i kątowego badanego przekładnika prądowego z rdzeniem toroidalnym wykonanym z permaloju Ni80Fe20. (**Pomiary błędów prądowego i kątowego przekładnika prądowego w warunkach transformacji prądów odkształconych).***

Keywords: Current transformer (CT), current error, phase displacement, sinusoidal conductive disturbances, distorted current.
Słowa kluczowe: Przekładnik prądowy, błąd prądowy, błąd kątowy, sinusoidalne zaburzenia przewodzone, prąd odkształcony.

Introduction

During transformation of distorted signals through instrument transformers their metrological properties are being change [1 - 3]. In some conditions conductive disturbances causes an increase of current transformer (CT) current error and phase displacement, but even then, for main harmonic, CT should met the requirements of corresponding accuracy class in accordance with inductive current transformer standard [1 - 4]. This effect is caused by deterioration of both CT windings system operation conditions and its magnetic circuit properties e.g. initial permeability.

Measuring circuit

During the laboratory studies to the supplying voltage of the tested CT primary winding additional conductive disturbances are brought. Their level from the programmable power supply is selected in order to the expected value of the Total Harmonic Distortion factor of CT primary current (THD_I). Simplified diagram of the measuring circuit is presented in figure 1.

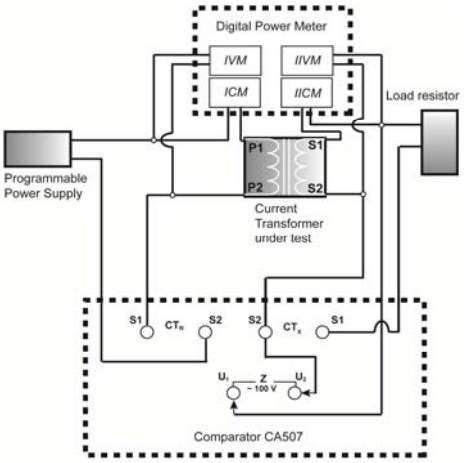

Fig.1. Simplified diagram of the measuring circuit

In figure 1 the following notations are use: IVM – voltage input of the first digital power meter module, ICM – current input of the first digital power meter module, IIVM – voltage input of the sec. digital power meter module, IICM – current input of the sec. digital power meter module.

Tested CT primary circuit is supplied by programmable power supply type Chroma model 61504, which is able to introduce additional harmonics into output voltage. In this mode of operation distorted voltage particular harmonics levels may be set manually by the user or by the value of THD factor [5]. Amplitude spectrums of sinusoidal current (I) and distorted currents for THD_I factors equal 20% (II) and 40% (III) are presented in figure 2.

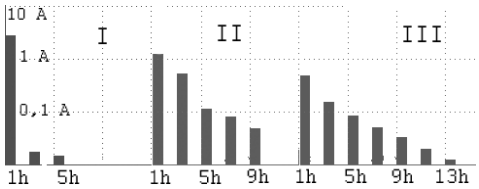

Fig.2. Amplitude spectrums of sinusoidal current (I) and distorted currents with THDI factors of 20% (II) and 40% (III)

For sinusoidal current (case I – figure 2) some distortion is present because voltage generated by used power supply is not a pure sin wave. Increase of THD_U factor of generated by power supply voltage cause proportional increase of tested CT primary current.

In the measurements of tested CT current error and phase displacement comparator type CA507 from Oltest company is used [4]. This device is design for measurements of current / voltage errors and phase displacement of current and voltage transformers with proper accuracy for given CT, VT classes. For distorted signal this comparator is measuring errors for 50 Hz harmonics. This means that the difference between current used for calculation of CT current error is limited to the difference between their 50 Hz harmonics RMS values and phase displacement is measured also between this primary harmonics.

In order to determine the levels of conductive disturbances in primary and secondary voltages and currents of tested CT digital power analyzer type WT 1600 manufactured by the Yokogawa company is use. This digital power meter allows direct measurement of voltage and current particular harmonics content and their RMS values in the range of frequency to 5000 Hz in accordance with the standard [6]. Used modules enable measurements of currents to 50A RMS and voltages to 1025V RMS with basic voltage and current measurements accuracy of 0.1% of reading. Effective input range is from 1 to ±110% of the measurement range for RMS and AC voltages and currents. For harmonics above 50 Hz to 1 kHz the measurements accuracy of their RMS value is 1% of reading + 0.1% of used range. For harmonics above 1 kHz to 2,5 kHz the measurements accuracy of their RMS value is 2% of reading + 0.1% of used range.

During the laboratory studies for the load of the tested CT both the ($\cos\varphi = 0{,}8$) load and resistors ($\cos\varphi \cong 1$) are use.

Results of laboratory studies

Laboratory studies are made for a CT of 5A / 5A current ratio with toroidal core made from permalloy Ni80Fe20 (0.2 mm tape), which cross-section is $s_{fe} \cong 0.0005$ m^2. The average flux path in the core is 0.34 m. Harmonics levels of conductive disturbances in the supplying voltage of the primary winding of tested CT, are set manually by the user for first test condition, when only one harmonic is injected to the supply voltage or by the programmable power supply unit and set by the user value of THD_U factor. THD_U factor value is set in such a way that THD_I factor could reach selected levels. In the second part of laboratory studies a specially developed method for testing the influence of sinusoidal conductive disturbances on current error and phase displacement of the CT is use. It involves injection of single conductive disturbance harmonic to the sinusoidal current of fundamental frequency 50 Hz at a specified level and increase frequency with fixed phase shift relative to the basic harmonic. There is no increase in errors as a result of current distortion, cause by conductive disturbances in the CT primary current, in condition when secondary winding is unloaded. When secondary winding load increases to 10 VA, there is no increase in errors as well, even for conductive disturbances level set to THD_I = 40%.

Significant changes in tested CT errors, in conditions of distorted currents transformation, is observed only when the secondary winding load is equal rated power 20 VA for 100% and higher values of rated primary current. Current error change characteristics with the change of conductive disturbances level for tested CT and measuring conditions, when a single selected level conductive disturbance harmonic is injected to the sinusoidal current of fundamental frequency 50 Hz and when multiple harmonics are injected for secondary winding load 20 VA and primary current 5 A are shown in Figure 3.

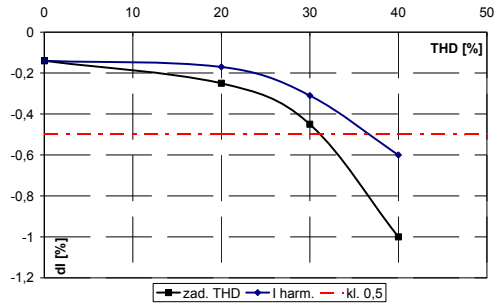

Fig.3. Current error change characteristics with the change of conductive disturbances level for tested CT

In measuring conditions when multiple harmonics are injected to the sinusoidal CT primary current of fundamental frequency 50 Hz, although their mutual phase shifts relatively to the main harmonic are often opposite, the influence of conductive disturbances on current errors is much larger, then for one harmonics for the same rms value of transformed current and secondary winding load. This may be due to interferences between harmonics, which increases the impact of conductive disturbances on the accuracy of the CT for main harmonic 50 Hz. Current error change characteristics presented in Figure 3 shows that for multiple harmonics of conductive disturbances in transformed by tested CT current the limits set for 0,5 CT accuracy class are exceeded for THD_I equal about 31% and for one harmonic of conductive disturbance in that current this limits are exceeded for THD_I equal about 36%.

Phase displacement change characteristics with the change of conductive disturbances level for tested CT and measuring conditions from Figure 3 are shown in Figure 4.

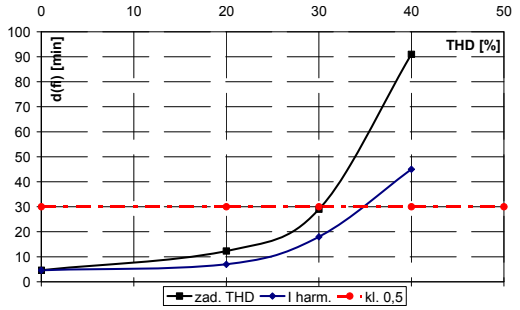

Fig.4. Phase displacement change characteristics with the change of conductive disturbances level for tested CT

In test conditions when multiple harmonics are injected to the sinusoidal CT primary current of fundamental frequency 50 Hz the influence of conductive disturbances on phase displacement is also much larger, then for one harmonics for the same rms value of transformed current and secondary winding load. Phase displacement change characteristics presented in Figure 4 shows that for multiple harmonics of conductive disturbances the limits set for 0,5 CT accuracy class are exceeded for THD_I equal about 30% and for one harmonic of conductive disturbance in that current this limits are exceeded for THD_I equal about 35%.

Conclusions

- Analysis of the results form the laboratory studies shows, that conductive disturbances in the CT primary current, in some measuring conditions, cause increase of its current error and phase displacement and decrease of accuracy for 50 Hz main harmonic. The reason of this phenomena is the change of the magnetic circuit properties of the current transformer for distorted current in relation to its properties for sinusoidal current.
- The results of this laboratory studies indicate the ineffectiveness of the method of distorted current generation when multiple harmonics are injected to the sinusoidal CT primary current of fundamental frequency 50 Hz in testing the accuracy of CT transformation for distorted current. This follows from the fact that due to the interference between conductive disturbance harmonics the combined effect of their influence on CT errors for 50 Hz harmonic is greater than from a single conductive disturbance harmonic of the same value in same measuring conditions.

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