ERROR OF CURRENT TRANSFORMERS WITH A HALF-WAVE RECTIFIED PRIMARY CURRENT

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Abstract. In many applications of the current transformers (CT) there is a requirement for operating with a half-wave rectified primary current. The specific features characterizing the operating regime of these current transformers under the conditions considered are a result of the large direct-current component in the primary current, generated when it is rectified as a half wave. The purpose of the present work is to define the power error of current transformers with a half-wave rectified primary current. The analysis is performed by using the software product PSpice.

Keywords: power error, current transformers (CT), half-wave rectified primary current.

INTRODUCTION

In many applications of current transformers (CT) there is a requirement for operating with a half-wave rectified primary current [1], [2], [3]. One such application is their use as connecting measuring transformers in static electronic watt-hour meters. These watt-hour meters are intended for measuring the active energy in single- and three-phase networks for alternating current with frequency within 45 to 65 Hz [2]. Regarding watt-hour meters connected by CT, in the norm [2] there is a requirement concerning the admissible basic error in the presence of direct current component in current circuits.

In known publications there are no discussions treating CT errors for a half-wave rectified primary current [1], [4], [5]. Physical aspects of the processes and specific characteristics of the operational mode of CT with a large direct component in the primary current are considered in an earlier publication [4].

The purpose of the present work is to define the power error of current transformers with a half-wave rectified primary current. The analysis is performed by using the software product PSpice.

DEFINING THE PROBLEM

A diagram for testing the effect of the direct current component on the error of electronic watt-hour meters connected by CT is shown in Fig. 1 [2].

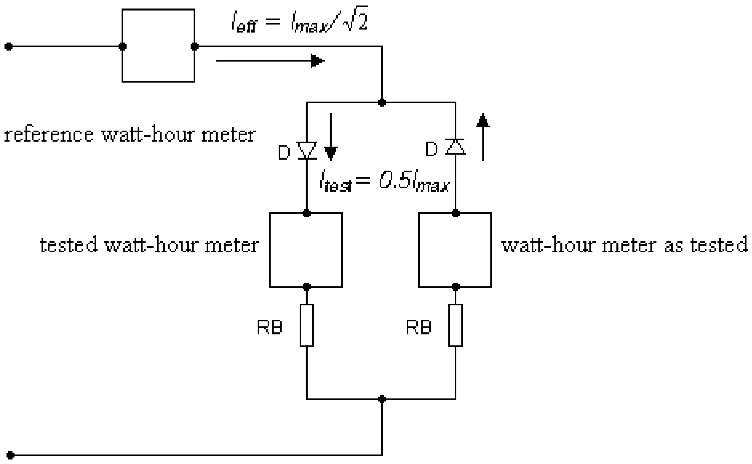

Figure 1. Experimental setup for determining the error of electronic watt-hour meters for a half-wave rectified primary current**.**

The circuit should meet the following requirements:

1. The balancing impedance R_B should be equal to that of the tested watt-hour meter or replaced by a watt-hour meter of the same type.

2. The effect of the direct component in the alternating current circuit should be tested at $I_{test}= 0.5I_{max}$. This condition should be realized with alternating current $I_{eff} = I_{max}/\sqrt{2}$, where I_{max} is the maximal current value indicated on the label of the tested watt-hour meter.

Here the admissible error of electronic watt-hour meters connected by CT with a class of accuracy 1 is 3 %, and for classes of accuracy 2 and 3 is 6 %. It is determined at cos φ = 1 for pure active load; cos φ = 0.5 for inductive load; and cos φ = 0.8 for capacitive load.

Having in mind these requirements, two analogous circuits for examining the effect of the direct current component by means of the software product of Design Center (PSPice) [6], [7], are developed. There is no CT connected in the first circuit shown in Fig. 2.

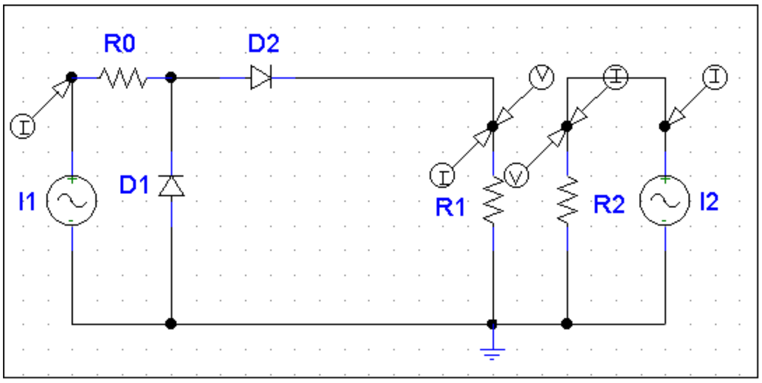

Figure 2. A circuit for determining the active powers without CT.

This circuit allows determining the average value of the active power measured by the tested watt-hour meter P_{test} - AVG(V(R2:2)*I(R1)), as well as the average value of the active power measured by the reference watt-hour meter P_{total} - AVG(V(R2:2)*I(I1)).

The second circuit shown in Fig. 3 is with CT with a linear magnetic core. It allows determining the average value of the active power measured by the tested watt-hour meter in the presence of CT, namely P_{testCT} - AVG(V(R2:2)*I(R1)), as well as the average value of the active power measured by the reference watt-hour meter P_{total} - AVG(V(R2:2)*I(R1)).

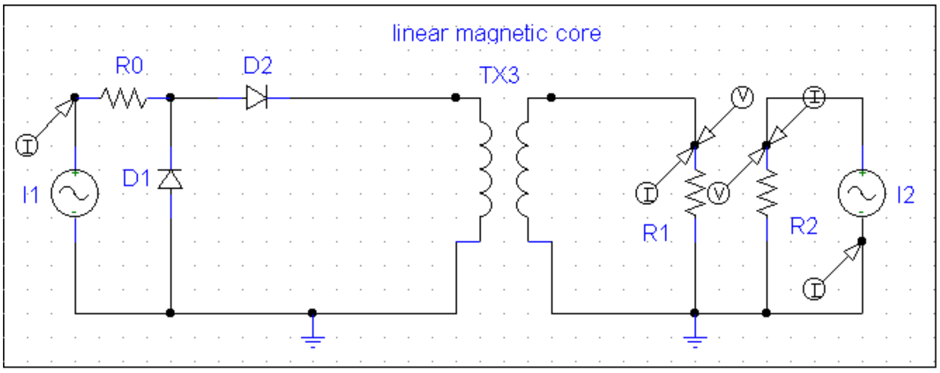

Figure 3. A circuit for determining the active powers with CT**.**

Both circuits use a source of sinusoidal current as a power supply source and two diodes by which a half-period mode is simulated in the circuit.

The preset values of the circuit components are based on preliminary calculations of experimental specimens which are in conformity with the requirements of standards [2], [3]. The equivalent circuit used for simulating the operation of tested watt-hour meter consists of a source of half-wave rectified current and a source of sinusoidal voltage that is represented by a current source and resistance.

The error ε_{PEM} of the tested electronic watt-hour meter is obtained from the expression:

(1)
$$\varepsilon_{PEM} = \frac{P_{test} - 1/2P_{total}}{1/2P_{total}} \cdot 100,\%$$

,where:
P_{test} - average value of the active power measured by the tested watt-hour meter;
P_{total} - average value of the active power measured by the reference watt-hour meter.

The error ε_{PEMCT} of the tested electronic watt-hour meter connected with CT is obtained from the expression:

(2)
$$\varepsilon_{PEMCT} = \frac{P_{testCT} - 1/2P_{total}}{1/2P_{total}} \cdot 100,\%$$

P_{testCT} - average value of the active power measured by the tested watt-hour meter in the presence of CT;

The CT power error for a half-wave rectified primary current is determined as the difference of the two errors:

(3) $$\pm \varepsilon_{PCT} = \varepsilon_{PEMCT} \mp \varepsilon_{PEM} ,\%$$

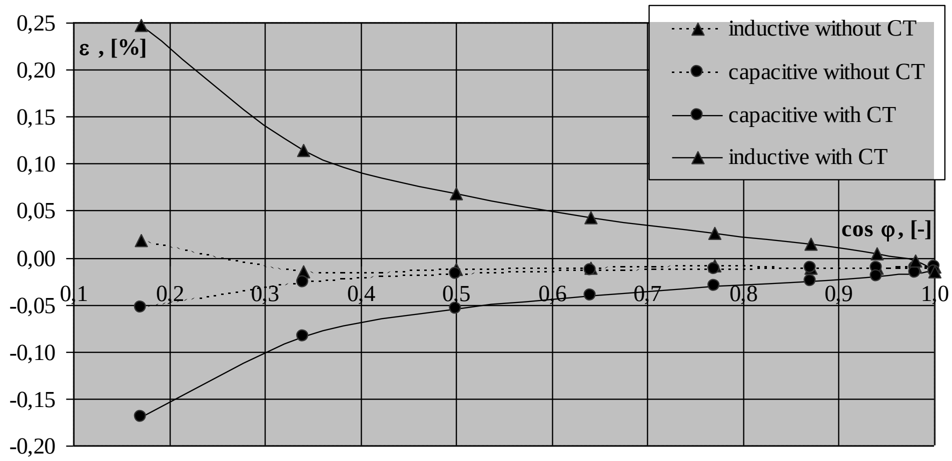

Figure 4. The errors of the tested electronic watt-hour meter connected with or without CT.

The waveforms of the instantaneous and average active powers are shown in Figures 5, 6, and 7 for the tested and reference electronic watt-hour meters during a transient process in the presence of CT at different loads.

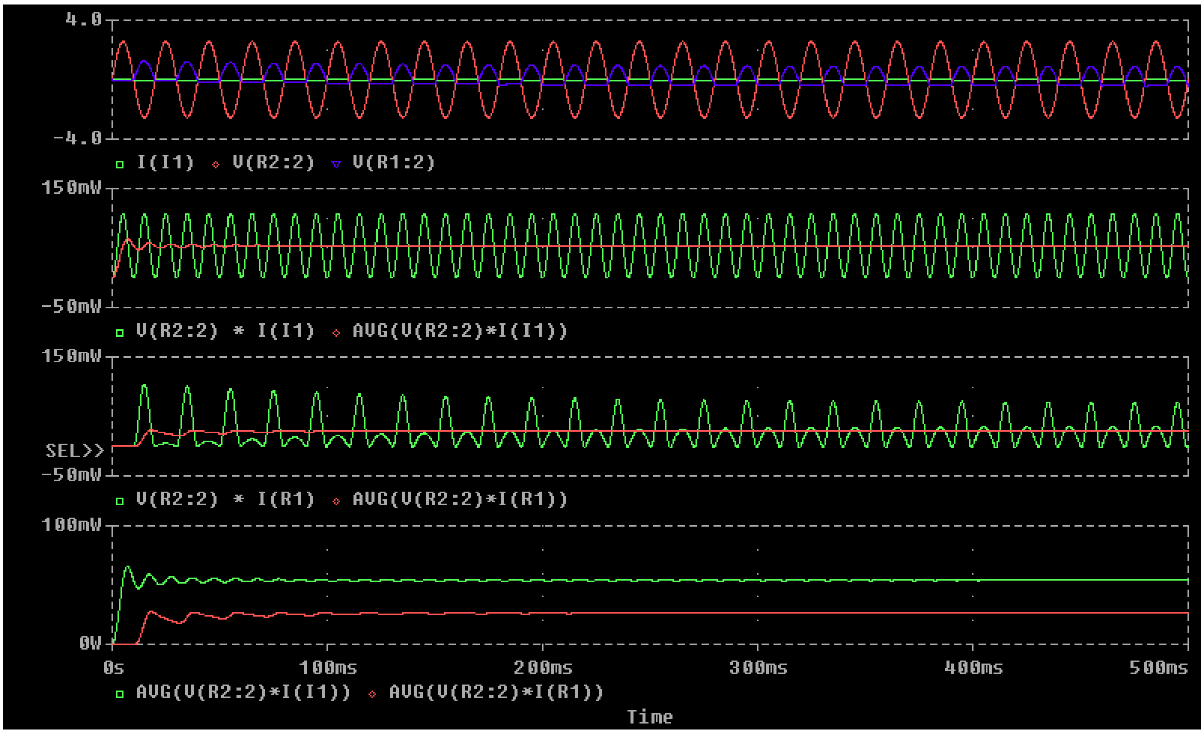

Figure 5. For active load cos φ = 1.

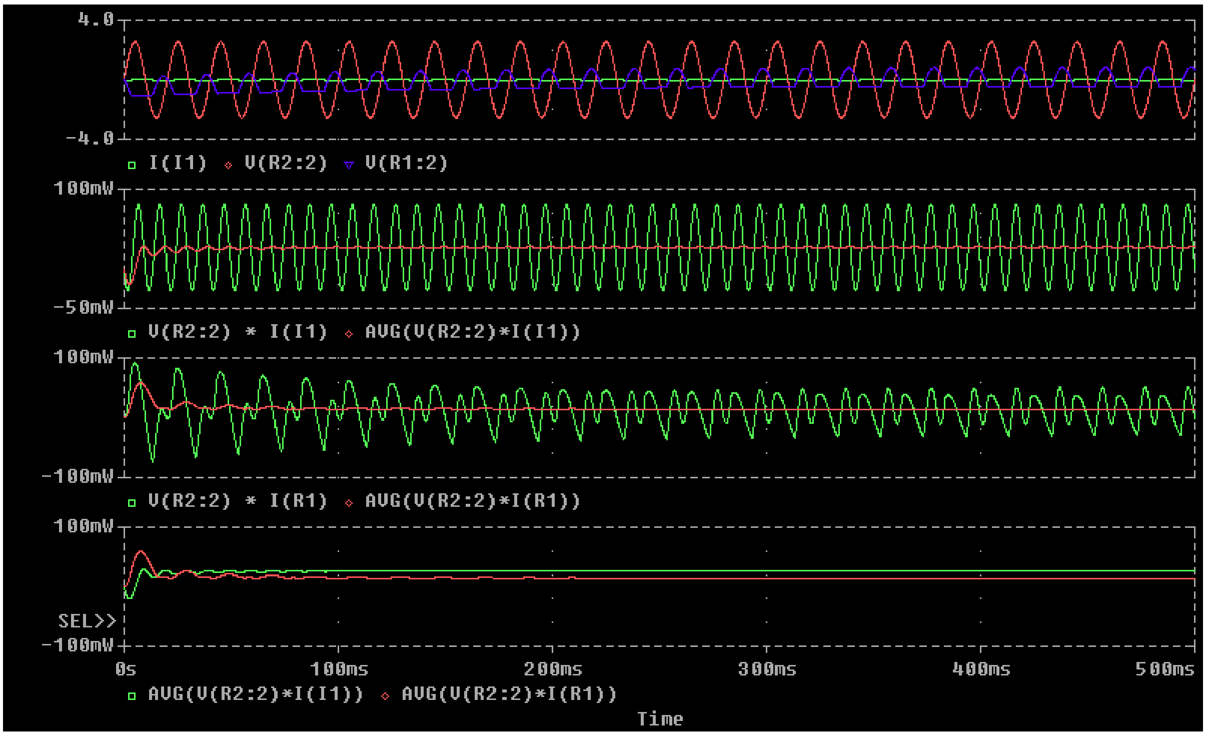

Figure 6. For inductive load cos φ = 0.5.

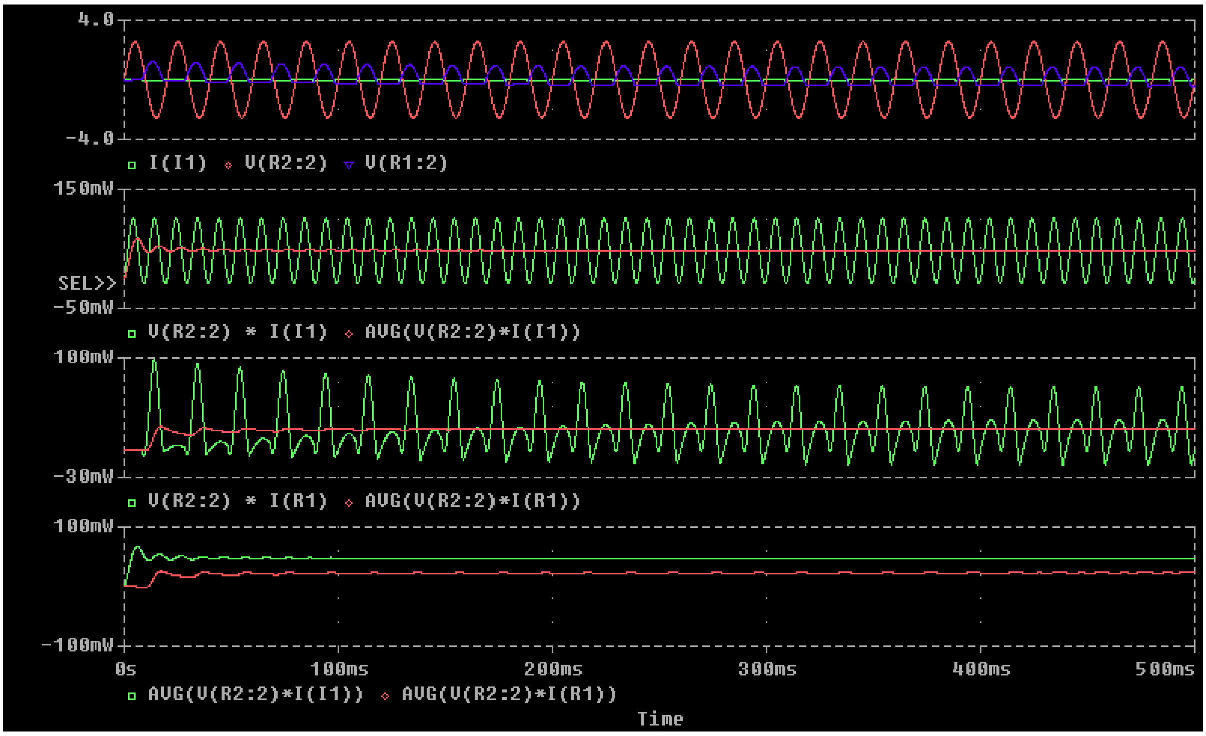

Figure 7. For capacitive load cos φ = 0.8.

CONCLUSIONS

Performing the analysis by means of the software product PSpice is suitable and convenient for investigating the effect of a direct current component on the error of electronic wattmeters connected by CT.

It is demonstrated that in this way it is possible to determine not only the total power error, but also the power error introduced by the connecting CT only.

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