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Daniel DUSZA, Bartłomiej RZEPECKI*

MAGNETIZING CURRENT EFFECT MINIMIZATION IN CURRENT TRANSFORMERS

Magnetizing current effect minimization in current transformers is considered in this paper. Double-core current transformer operation is described in the following text. The influence of the magnetizing current, which is a significant element of current transformer's error, has been minimized in a new type of double-core current transformer connection. The accuracy evaluation of built double-core current transformer has been carried out according to obtained transformation precision.

1. INTRODUCTION

Measuring power in the system has always been a difficulty to carry out. To achieve credible of power measurement results a precise current measurement has to be performed. Current measurement realized using current transformers requires actual current transformation.

The measurements carried out in the system has to be very precise. Measurement instrument accuracy class should be at least 0,01. Another issue is that high amplitude current causes difficulties in the measurements.

Last issue related to such measurement is referring to measured signal’s shape. Measured signal has to be an even, periodic function. That means it has to change periodically and it can contain only two extrema per period.

In this paper a description how the influence of polarization current i_o to the system can be minimized to reduce the error of double-core CT is provided. Presented results are focused only to double-core current transformer’s angle error because authors considered this solution only for supply current zero-crossing moment localization application.

* Politechnika Wrocławska, Instytut Maszyn, Napędów i Pomiarów Elektrycznych, ul. Smoluchowskiego 19, 50-372 Wrocław, daniel.dusza@pwr.wroc.pl, bartlomiej.rzepecki@pwr.wroc.pl doktorant w Instytucie Energoelektryki

2. DOUBLE-CORE CURRENT TRANSFORMER WITH ERROR MINIMIZATION

Both the transformer windings are located on a common core and are coupled magnetically. This facilitates the flow of electric energy from the primary to the secondary circuit. Figure 1 shows schematically the magnetic fluxes. Their balance causes the proportionality of the primary and secondary current at secondary winding short circuit connection [1].

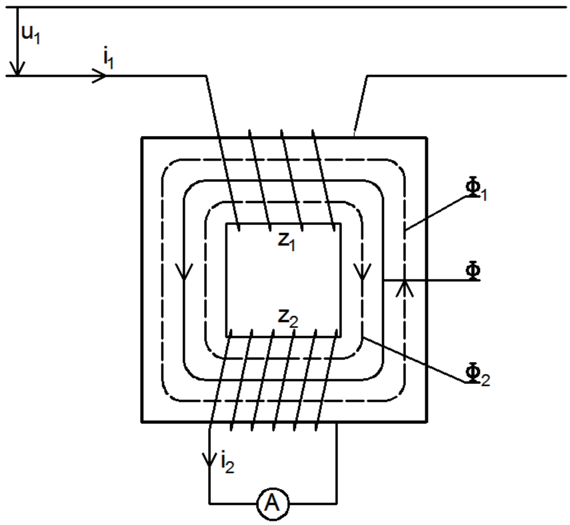

Fig. 1. Streams induced in the magnetic circuit transformer [1]

Primary current $i_1$value depends on the primary circuit and can be considered as a reference value for the transformer. If i_1 is flowing through the primary winding it induces a magnetic flux in the circuit. Induced flux violates identically as the primary current violates.

If the primary current will have a sinusoidal flux Φ_1 then formed by the flow of current also has a sinusoidal shape. This flow induces a voltage in the secondary winding which causes current i_2 flow in the secondary winding. The i_2 current in the secondary winding produces flux Φ_2 in the core. According to Lenz law flux Φ_1 opposes flux Φ_2. If fluxes shape is sinusoidal the phase shift between them is $\pi/2$. As a result of magnetic interactions of the two coils, the magnetic core forms approximately sinusoidal flux of actual values which have been the difference of momentary flows Φ_1 and Φ_2:

$$\Phi(t) = \Phi_1(t) - \Phi_2(t) , \qquad (2.1)$$

where:

Φ – the resultant stream,

Φ_1 – primary stream,

Φ_2 – secondary stream.

Equation (2.1) can be expressed as the difference of magnetic field intensity produced by the primary and secondary current flow:

$$H_0 = H_1 - H_2 , \tag{2.2}$$

where:

H_0 – resultant field strength on the average length of the magnetic core,

H_1 – primary field strength,

H_2 – secondary field strength.

If we assume that the core has toroidal shape with homogeneous features, high magnetic permeability and constant cross-section, equation (2.2) can be represented as [1], [2]:

$$\frac{i_0 z_1}{l_0} = \frac{i_1 z_1}{l_0} - \frac{i_2 z_2}{l_0} , \tag{2.3}$$

which follows to:

$$i_0 z_1 = i_1 z_1 - i_2 z_2 , \tag{2.4}$$

where:

z_1, z_2 – number of turns of the primary and secondary winding,

l_0 – the average length of the magnetic core,

i_0 – polarization current generating a magnetic flux in the core.

The polarization current is responsible for magnetic losses in the core. It is also responsible for errors of the current transformer. There are two types of errors for current transformers: amplitude and phase error.

Amplitude error has an effect on secondary current amplitude value. Secondary current amplitude depends not only on the ratio of the transformer but also on the value of amplitude error.

The phase error is responsible for phase shift between the primary and secondary current. If the phase shift value is not constant or approximately constant in considered current range, the error of current transformer is very high.

That means that polarization current is responsible for the error of the current transformer consisting of amplitude and phase error. The thicker the magnetic core is, the lower the magnetic current i_0 influence to current transformer's error is. This statement is based on the fact that magnetizing current i_0 depends on quality and quantity of magnetic core.

An innovative connection type of double-core connection type has been discovered at Wrocław University of Technology. The new connection consists of two current transformers. The first, called as the main current transformer, consists of:

- primary winding,
- toroidal magnetic core,
- two secondary windings.

The first secondary side winding is considered as the main winding. The second winding is considered as supplementary or additional wiring.

Second current transformer has a regular structure for a current transformer. It consists of:

- primary winding,
- toroidal magnetic core,
- secondary winding.

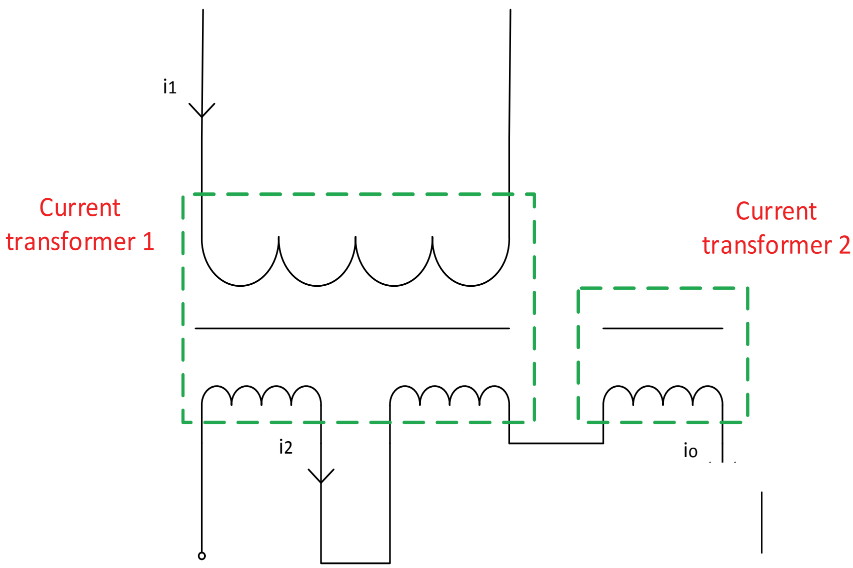

Fig. 2. An innovative connection type of a double-core current transformer diagram

The main secondary winding end of the main current transformer is connected to the beginning of its additional winding. The additional winding of main current transformer is connected to supplementary current transformer's winding.

Supplementary current transformer has only one winding connected to the system. That is why only one winding of supplementary current transformer is considered in the diagram (Fig. 2).

The measurement algorithm idea is to measure the output signals as voltage drops at resistors connected to the secondary side of the double-core CT in a specific way.

The principal secondary winding of the main current transformer is connected to main R_1 resistor. Its additional winding attached to supplementary current transformer's winding is connected to R_2 resistor. The auxiliary magnetic core (*Current* *transformer 2*) is responsible for minimizing polarization current i_0 influence to double-core current transformer's accuracy.

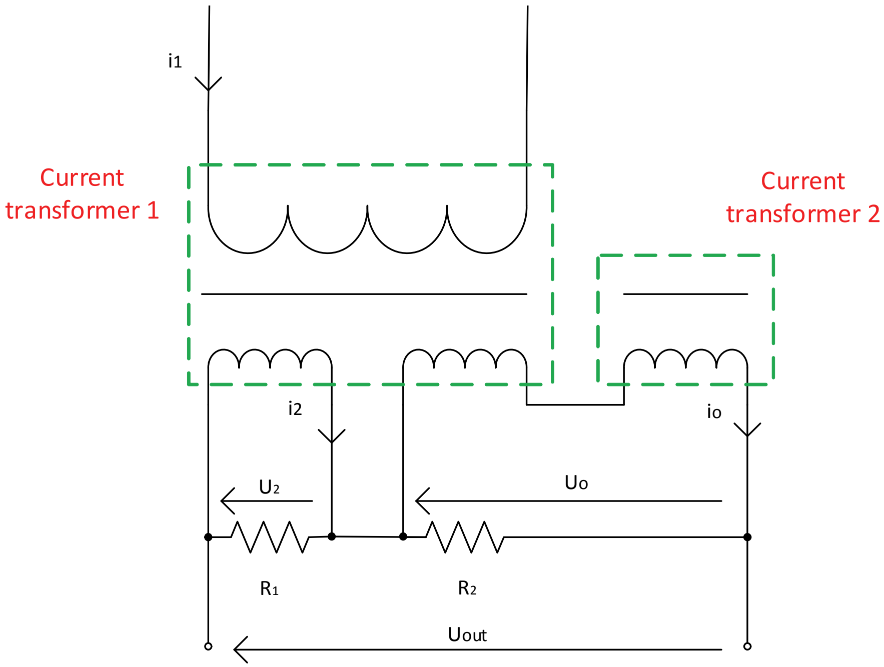

Fig. 3. Testing the double-core current transformer measurement error circuit

Figure 3 presents the circuit used to measure the error of double-core current transformer. R_1 resistor value has been set to 2.5 Ω. It has been constructed from 88 parallel connected resistors. High amount of resistors effects in high precision of the measurement and limits the value of current flowing through single element.

Output current is measured based on U_{out} voltage. U_0 is representing i_o magnetizing current value. Based on the relationship:

$$U_{out} = U_2 + U_0 \tag{2.5}$$

where:

U_2 – voltage drop on R_1 resistor caused by i_2 secondary current flow,

U_0 – voltage drop on R_2 resistor caused by i_o magnetizing current flow.

Magnetizing current i_o influence is being eliminated in the output which in effect gives very precise result of the transformation. In effect i_1 current is equal to sum of i_2 and i_o currents. Starting R_2 resistance value was set as 2.5 Ω and concluded of eight 20 Ω resistors connected in parallel. By improving R_2 resistance it is possible to decrease the error of the current transformer approaching to zero [3].

3. MEASUREMENT RESULTS

In this section final results will judge if the magnetizing current effect can be minimized by using described type of minimization method. Presented results consist of values obtained before the optimization process and after successful optimization. Detailed values of the current transformer error during the optimization process are presented here as well.

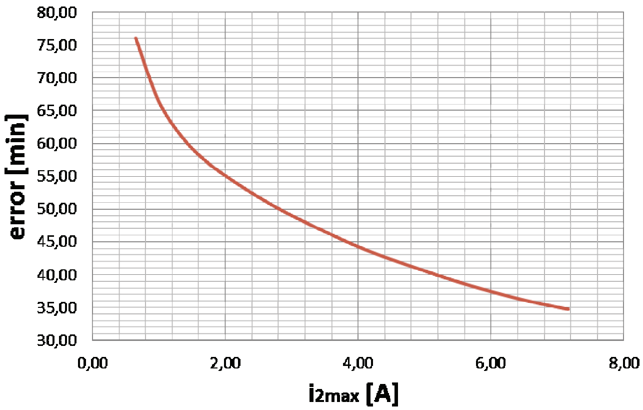

Fig. 4. Current transformer error with no compensation

Figure 4 presents the current transformer error result in non-compensation structure. The waveform shape of the error depending on the secondary side current magnitude i_{2max} does is not linear which is an obvious negative result. The error value changes approximately 40 minutes in the following current range. The structure of the current transformer has been changed in a way to reduce the error value and obtain a linear value of the error for the current range. The load circuit of the transformer has been changed to optimize the circuit.

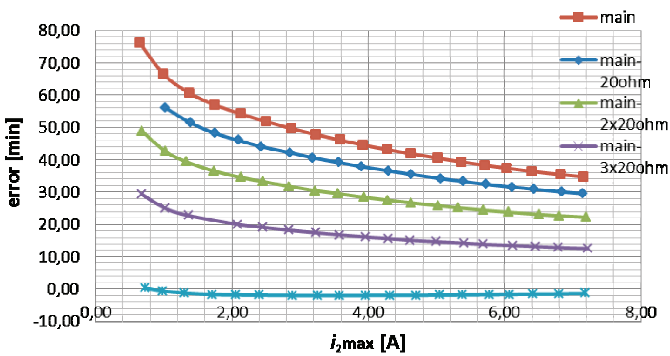

Fig. 5. Optimization process of the current transformer circuit results

The optimization process leads to obtain approximately constant error value of the current transformer. The circuit optimization process has been carried out by changing the load attributes, e.g., *main-20ohm* means decreasing the parallel resistance by 20 ohms. After several steps of improving the circuit following current transformer's error results have been obtained:

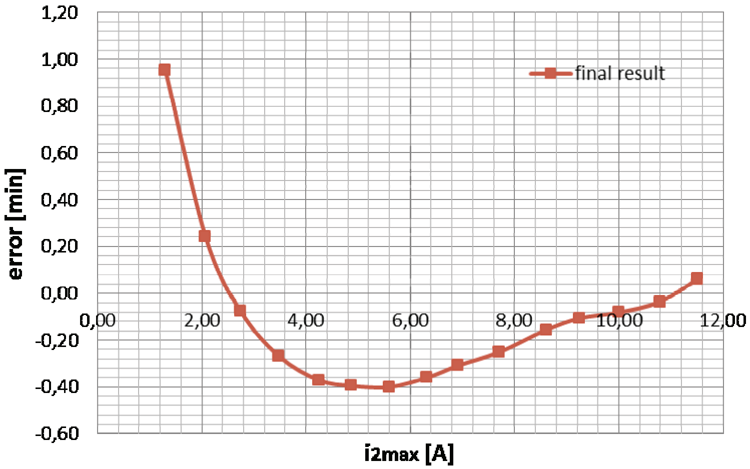

Fig. 6. Double-core current transformer's error final result

Final result obtained for the current transformer's error does not exceed 1 minute difference in the following current range, while amplitude error was lower than 0,01%. For the greater range current the error waveform is approximately constant in comparison to previous results [3].

4. CONCLUSIONS

An innovative type of connection has been used for double-core current transformer has been successfully applied. Constructed double-core current transformer's measurement error and optimization algorithm has been successfully carried out.

The double-core current transformer optimization process consisted of few steps of optimization. Improving the circuit by correcting i_o magnetizing current influence to the system occurred to work properly and according to theoretical assumptions.

Constructed double-core current transformer operates at high precision. The lowest value of current transformer's error was obtained at –0,04 min level. That makes it a device of approximately 0,005 accuracy level for determined current range. Those results follow to a conclusion that new connection that was used in the project gives high precision level in current measurement.

Used double-core current transformer error varies between approximately –0,4 and 1 minute in full current range. This result can be considered as almost constant because the error oscillation is not uncertain. These oscillations are a result of differences in magnetic features of used current transformer.

At such level high precision level used double-core current transformer connection is highly recommended to be used as a precise current measuring device. Of course built structure can still be improved depending on desired double-core current transformer error value.

REFERENCES

[1] KOSZMIDER A., Olak J., Piotrowski Z., *Przekładniki prądowe*, Wydawnictwa Naukowo-Techniczne, Warszawa 1985.
[2] SOIŃSKI M., *Materiały magnetyczne w technice*, COSiW SEP, Warszawa 2006.
[3] RZEPECKI B., *Application of double-core current transformers in supply current zero-crossing localization*, Master thesis, PolitechnikaWrocławska.