Investigation of the Amplitude and Phase Errors of Transformer Current to Voltage Converters

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Abstract:

When the industrial power network is tracked, it is necessary that the AC current and power to be measured. A significant way for such measurement is available when current transformer converters are used. In the present paper a study of the amplitude error and phase difference is presented for three different current converters: A current transformer with a resistive load; a current transformer loaded with an operational amplifier, working as a I - U converter and compensated current transformer.

Enhancement of characteristics of modern instrumentation is undoubtedly connected with recent developments on microprocessor technologies and digital signal processing. Higher accuracies, fast response times and considerable reduction of the mass and physical dimensions of the converters are a result from the above developments. When the industrial power network is tracked, it is necessary that the AC current and power to be measured. A significant way for such measurement is available when current transformer converters are used, due to electrical isolation provided by these transformers and proper matching of electrical parameters. Researching for new circuit ideas and state-of-the-art decisions for further enhancement reduce the physical dimensions of the primary transformer converters.

In the present paper a study of the amplitude error and phase difference is presented for three different current converters: A current transformer with a resistive load; a current transformer loaded with an operational amplifier, working as a I - U converter and compensated current transformer.

Torroidal type transformer with feromagnetic core is used in the research. At the very beginning of the study some experiments were carried out in order to obtain real initial magnetic curve, magnetic saturation and coercive force values. A new item

KMnNi_3600 was added to the magnetic.lib library of the PSPICE Analogue simulator.

Analysis of a Current Transformer (Fig.1)

Assumptions below being drawn up in the circuit to be analysed:

- The nominal input currents of the measuring converters in the industrial power network is 1A and 5A;
- Output signal is fed to an Analogue to Digital Converter with a 5V DC input range.

A transformer with a maximum resistive load R_L=500Ω and 1:1000 winding ratio was elected while considering the above assumptions.

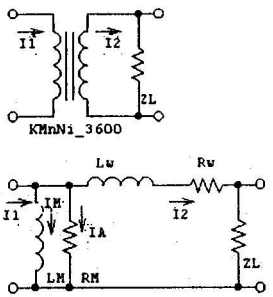

Fig.1a Current Transformer

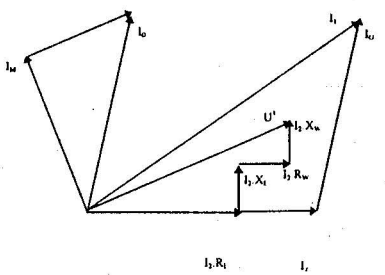

Fig.1b *Vector Diagram of a Current Transformer*

Amplitude error $\delta = (I_1 - I_4)/I_1$ and phase difference $\Delta\varphi = \varphi(I_1) - \varphi(I_2)$ were analysed. A frequency influence on the amplitude and phase errors for the load R_L= 5, 50, 500Ω is shown in Fig.2. Effect of the input current influence on the current and phase errors for different loads 50Ω and 500Ω is given in Fig.3. It is assumed that the winding resistance and inductance dissipation as zero in the research.

It is apparent from the analysis that:

1. The error is reduced as a result of lowering of the magnetization current when the frequency is increased and load resistance is decreased.
2. Higher values for the error of the input current is measured as a result of saturation of the core.

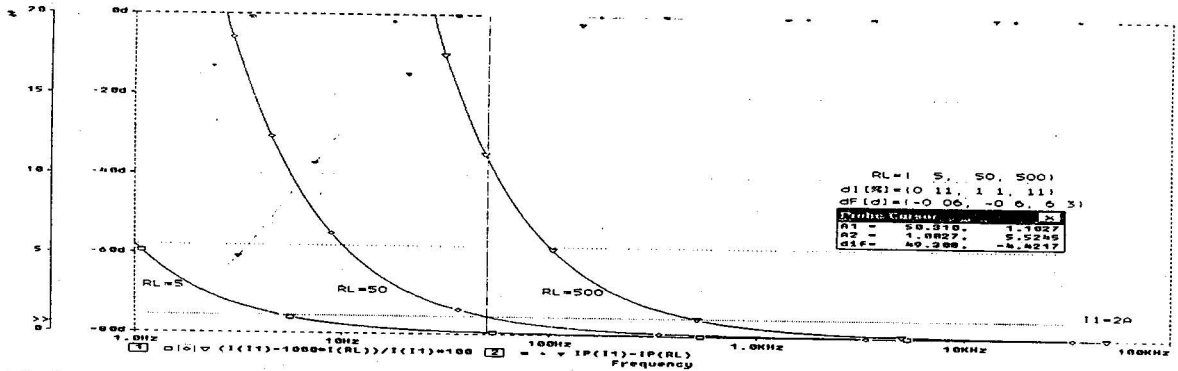

Fig.2 Amplitude error and phase difference for Current Transforemer

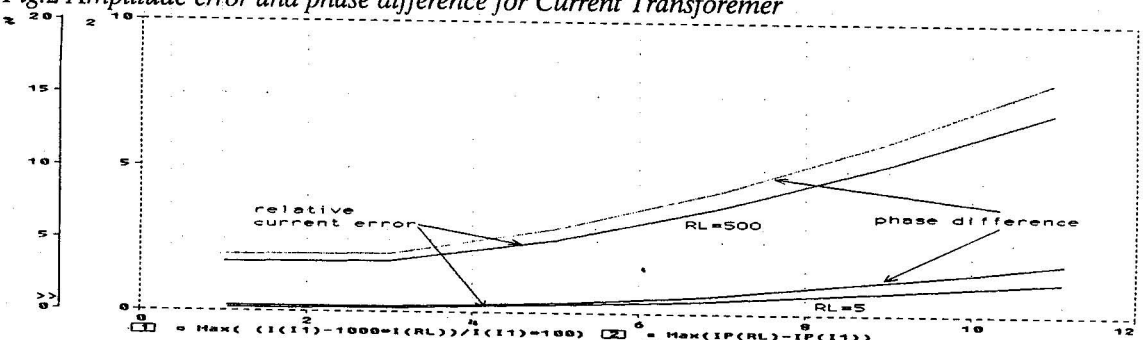

Fig.3 Converter's Input Current influence on the amplitude error and phase difference

Analysis of a Current Transformer Followed by a Current to Voltage Operational Amplifier

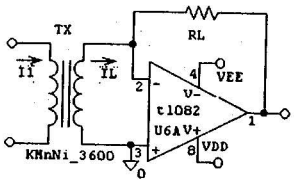

Fig.4 Current converter followed by a current to voltage operational amplifier

The results obtained from the study of the circuit in Fig.1 related to the influence of the load resistance on the error show that, when the resistance approaches zero, the error gets negligible. Practically core physical dimensions smaller, thinner the second winding diameter. About 50Ω resistance for the secondary winding was obtained in this case. It means that, the circuit in Fig.4 has greater errors compared to current transformer with 50Ω load (Fig.3). Errors introduced by the operational amplifier are added to them. Nevertheless they are small due to large feedback coefficient.

Analysis of a Compensated Current Transformer (Fig.5)

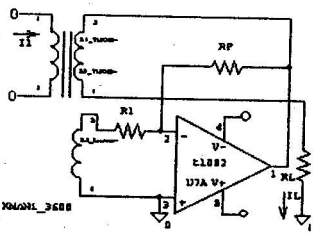

Fig.5 A compensated current transformer

Description of the operation of the circuit and its mathematical model is given detailed in [1]. In the present paper simulation results with PSPICE analog simulator are shown. The frequency influence on the amplitude error and phase difference are shown in Fig.6 for different feedback coefficients of the operational amplifier, which works with a parallel-negative-voltage feedback. Influence of the input current is shown in Fig.7.

Measured values and the simulations show that:

1. Considerable reduction of error can be achieved by a compensating winding and an extra op. amp circuit.

2. The error basically is defined by the parameters of the operational amplifier such as: input resistance and frequency range. Amplitude error is reduced by 10 times when an operational amplifier with series feedback is applied due to higher input resistance of the circuit.

3. Higher values for the error are measured for higher values of input current. This is explained by the non-linear characteristic of the amplifier used.

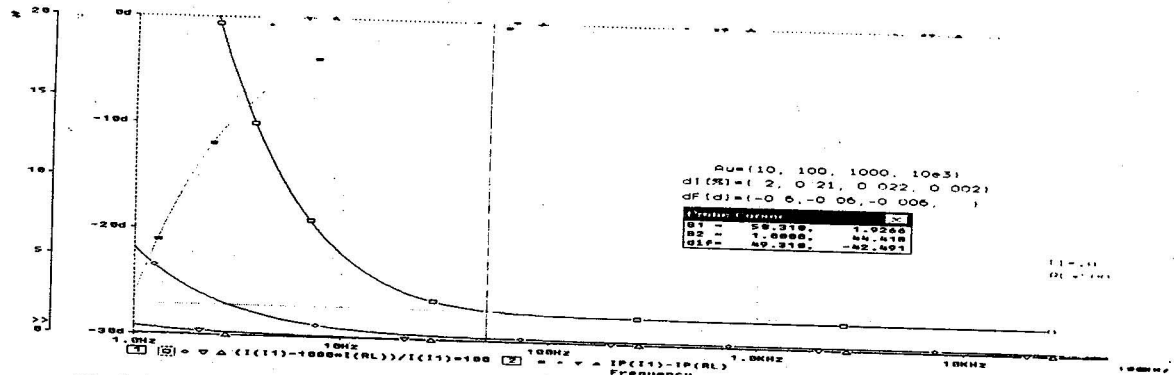

Fig.6 Amplitude error and phase difference of Compensated current transformer

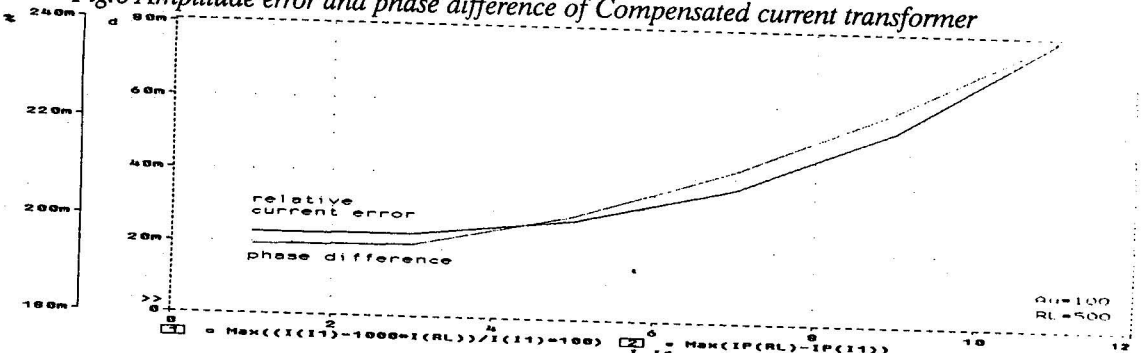

Fig.7 Amplitude error and phase difference for I_1=1÷10A of compensated current transformer

Conclusions

Physical dimensions of the current transformer converter is related with the dimensions of the core. Phase and amplitude errors are worsen when the magnetic core dimensions are reduced. Application of a compensated current transformer allows a small physical dimensions cores to be used.

References :

[1] St. Ovcharov, M. Bogdanov, "Investigation of Current to Voltage Cokpensated Transformer", Electronics'96, Sozopol 1996

[2] J.Ramboz, J.West, "Watt Transfer Standard", IEEE Transaction on Instrunebtation and Measurements, Vol 40, No 2, April 1991

[3] Nile Oldham, O.Petersons, B.C.Waltrip, "Audio-Frequency Current Comparator Power Bridge: Development and Design Considerations", IEEE Transaction on Instrunebtation and Measurements, Vol 38, No 2, April 1989