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THE MATHEMATICAL MODELS OF COMPENSATED ELECTRONIC CURRENT AND VOLTAGE TRANSDUCERS

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Electronic current and voltage transducers with magnetic flux compensation in magnetic core have been described in the paper. The models of electronic transducers have been taken into consideration to explain reasons for the limitation of working passband of electronic transducers. Finally, applications of the models were discussed.

1. INTRODUCTION

Nowadays electronic transducers with magnetic flux compensation are very often applied in power electronic industrial devices [1, 2, 3]. The reasons for the increased popularity of electronic current and voltage transducers are: their simplicity, construction tested in practice and small dimensions. Moreover, fast development of power electronic devices induces continuous demand for measurement devices with better and better metrological properties. Therefore current and voltage transducers with magnetic flux compensation are very often applied in measurements, despite of its 25-year history.

The main fields where power electronic devices are used are: the electric drive, the high efficiency converters used for inductive and capacitive warming, different kinds of feeders of alternating and direct currents, rectifiers, inverters and energy converters.

Unfortunately, the producer of electronic transducers [4] does not publish their working passband. It causes big difficulties to adjust transducer for measurement of deformed signals properly. The results of laboratory research [3] demonstrate that electronic transducers produced by LEM can measure deformed signals whose frequency belongs to working band of the electronic block which controls the circuit compensating flux in the core.

Taking into account numerous applications of electronic transducers in the power electronics and the fact that previous electronic transducer models [2, 5, 6] have appeared to be insufficient during simulation tests for distorted primary signals, new models of electronic current and voltage transducers were constructed [7, 8] and described in the paper.

2. ELECTRONIC CURRENT AND VOLTAGE TRANSDUCERS

Electronic transducers are adapted to transform direct and alternating currents/voltages with galvanic separation between primary and secondary circuits. Fig.1 presents a functional diagram of electronic transducers. The structure of mathematical models of electronic current and voltage transducers, described in the next paragraph, reflect their performance. That is why author will refer to these models in the chapter.

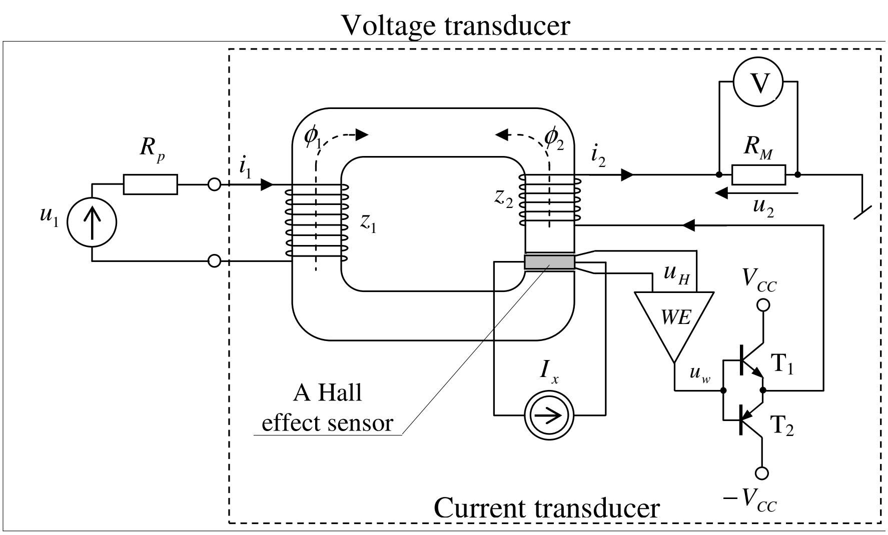

Fig. 1. The functional diagram of electronic current and voltage transducers

The major element of current and voltage transducers is the magnetic core with an air-gap Two windings are placed. on the magnetic core: the first with z_1 turns and the second with z_2 turns. In the air-gap the Hall effect sensor is situated, that forces voltage u_H proportional to the magnetic induction B in the core and the air gap (Fig. 1). The output signal u_H of the sensor feeds the operational *WE* amplifier that controls the output voltage – u_w. Afterwards the u_w voltage supplies output power stage, created by two complementary connected transistors. The power stage works in fact like typical inverter block. Depending on the polarization of the voltage u_w only one transistor T_1 or T_2 is conducting and in the secondary circuit a compensating current – i_{2e} is forced (Fig. 2, Fig. 3). Thereby, in the secondary circuit flows the current $i_2 = i_{2t} + i_{2e}$. The i_{2t} current is produced like in a classical current transformer (it was not marked in Fig. 1, Fig. 2 and Fig. 3) and its contribution for i_2 current is small if electronic block works. If electronic block is saturated, i_{2t} current is dominant and i_{2e} current is negligibly small. The flow of i_{2e} current produces an additional magnetic flux ψ_e associated with the secondary winding, which compensates the main flux $\psi_t = z_2(\phi_2 - \phi_1)$ which is produced like in a classical current transformer (Fig. 2, Fig. 3). The *WE* amplification, Hall sensor coefficient, number of turns z_2 and direction of winding of the compensatory coils are chosen so that in a steady state in the core, the value of flux is near zero. This means that magnetic flow produced by the measured $i_1$current is compensated by magnetic flow produced by $i_2$current of the negative feedback loop: $i_1 z_1 = i_2 z_2$.

As contrasted with electronic current transducers, the primary winding of voltage transducers has more turns. Moreover, in series with primary winding, there is an additional R_p resistor (Fig. 1) forcing the flow of i_1 current in this winding, which is transformed like in electronic current transducer.

3. MATHEMATICAL MODELS O ELECTRONIC TRANSDUCERS

During identification process the author has tested the following electronic current: LA25-NP/SP13, LA25-NP, LA55-P and voltage: LV25-P, LV100 transducers. The formulated mathematical models of electronic transducers were presented in Fig. 2 and Fig. 3. Differences in construction of primary circuits of electronic transducers were also reflected in their models.

Both of mathematical models (Fig. 2, Fig. 3) consist of: classical current transformer's and electronic block (dotted line) models.

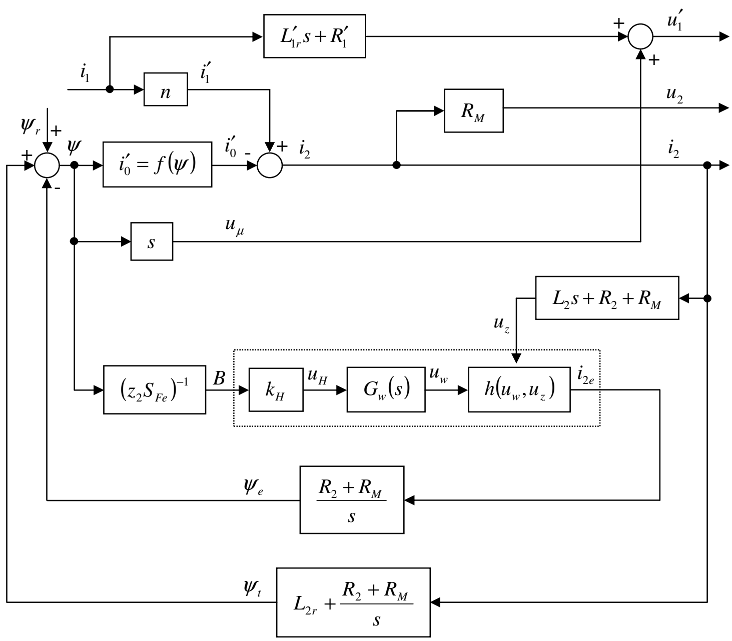

Fig. 2. The mathematical model of the electronic current transducer

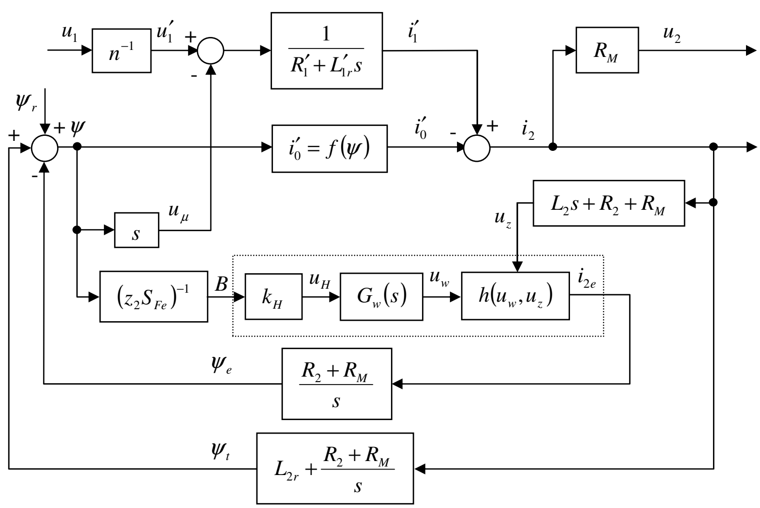

Fig. 3. The mathematical model of the electronic voltage transducer

Parameters connected with current transformer i.e.: R_1', L_{1r}', R_2, L_{2r}, R_M, ψ_r and n, determine correspondingly: resistance and leakage inductance of primary circuit (transferred to the secondary circuit), resistance and leakage inductance of secondary circuit, measuring resistance, magnetic associated flux residue and multiple of primary and secondary turns. Properties of the transducer magnetic core have been imitated in mathematical models (Fig. 2, Fig. 3) by $i_0' = f(\psi)$ blocks (where: i_0' and ψ describes respectively no-load current and magnetic flux associated with secondary winding) .

In the prposed mathematical models L_2 inductance of secondary winding was also taken into account, which does not exist in classical current transformer model. Nevertheless, it was proved during laboratory tests that the sum of voltage drops on compensating coil and measuring resistance have great impact on the saturation of complementary connected transistors.

In the electronic block part of the model there are the following parameters: the constant of the Hall effect sensor k_H, the first order transfer function of the operational amplifier *WE* - $G_w(s)$ and the function representing the power stage of the electronic block - $h(u_w,u_z)$ (imitated by Ebers-Moll model).

The electronic block task is to minimize magnetizing current value. It is realized by compensation of magnetic flux ψ_t associated with secondary winding that result in equilibration magnetic flows from currents i_1 and i_2.

If the electronic block is saturated, transduction is realized due to the classical current transformer and the current forced by the electronic circuit is negligibly small. In consequence metrological properties of electronic current and voltage transducers are worse in this mode of operation. Transformation of distorted current and voltage signals is also realized with significant error.

Such parameters as: R_1', L_{1r}', L_{2r}, ψ_r, k_H and functions coefficients: $G_w(s)$, $h(u_w,u_z)$ are not presented in documentation of electronic transducers. Therefore, the author has also implemented the Levenberg-Marquardt's method to estimate the unknown parameters.

The models with estimated parameters were very useful in determining border frequency of the electronic transducers working passband. Also the simulations of models have proved laboratory tests. It was found that parameters L_{1r}, k_H,, R_M and the third harmonic share in current/voltage transformed signals have the biggest influence on the electronic block cut-off.

4. CONCLUSIONS

Current and voltage transducer models with well identified parameters can contribute to the recognition of the metrological proprieties of electronic transducers and application of the models in processing of deformed signals. Another advantage, which results from the usage of such models is the possibility of unseeing them during research in working conditions different from normal, and secondly choosing the electronic transducer which would be optimal in a given measurement system.

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MODELE MATEMATYCZNE SKOMPENSOWANYCH ELEKTRONICZNYCH PRZEKŁADNIKÓW PRĄDOWYCH I NAPIĘCIOWYCH

Streszczenie

W artykule przedstawiono elektroniczne przekładniki prądowe i napięciowe z kompensacją strumienia magnetycznego w rdzeniu. Następnie opisano modele matematyczne tych przekładników, które pozwoliły wyjaśnić przyczyny ograniczenia częstotliwościowego pasma pracy elektronicznych przekładników. Natomiast zastosowania tych modeli omówiono na końcu.

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