Modified method of identification of mutual fractional-order inductance

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Abstract. The paper presents a method for identifying the parameters $M_\gamma$, $\gamma$ of a fractional-order transformer, which parameters $L_\beta_1$, $\beta_1$, $L_\beta_2$, $\beta_2$ have been previously determined. This method is based on the measurement of the phase resonance frequency in a few systems containing: the investigated fractional-order transformer and two standard capacitors. The measurements need to be performed only for one series opposite-aiding connection of the fractional-order transformer. The dependencies allowing the determination of the fractional-order mutual inductance parameters have been given.

1 Introduction

There are many works devoted to the analysis of systems with fractional-order elements $L_\beta$, $C_\alpha$, their realization and parameter identification, e.g. [1-3].

For several years, there has been a rapid growth of interest in fractional differential-integral calculus application in describing fractional-order magnetically-coupled coils systems [4-6]. The work [4] describes the concept and properties of such fractional-order coupled inductances. In [5], the electromagnetic Maxwell equations of the fractional-order mutual inductance are analyzed. The wireless power transmission system has been modeled as a fractional-order coupled coils system in [6]. The existence of fractional-order coupled coils (fractional-order transformer) implies the need to determine the parameters of the fractional-order elements. In [7], a method has been proposed for parameters identification of the fractional-order coils with an iron core, which is based on the approximation of the transient response to the unit-step voltage using the least squares method.

The paper is an extension and continuation of [8], where the new method for the identification of all the parameters $L_\beta_1$, $\beta_1$, $L_\beta_2$, $\beta_2$, $M_\gamma$, $\gamma$, of the fractional-order coupled inductances, has been proposed. The paper presents a proposal for a modified method of the identification of the fractional-order parameters $M_\gamma$, $\gamma$ of the mutual inductance, based on the phase resonance phenomenon in the series circuit of the class RLC compared to [8], without the need of the input impedance measurement in the combination of series and opposite-aiding connection of the transformer system.

2 Modification proposal

The equivalent circuit of the system for the parameters $\gamma$, $M_\gamma$ determination of the fractional-order mutual inductance, is shown in Fig. 1.

The circuit from Fig. 1 is supplied by the sinusoidal voltage source of adjustable frequency.

The circuit impedance, seen from the source terminals, is given by a formula:

$$Z(j\omega)=R+(j\omega)^{\beta_1}L_\beta_1+(j\omega)^{\beta_2}L_\beta_2 - 2(j\omega)^{\gamma}M_\gamma - \frac{1}{j\omega C}$$

where: $R$ - the equivalent resistance of the series connection of the coil resistances.

Transforming, the real and imaginary part of the impedance is:
The circuit from Fig. 1 has been supplied from a source with an adjustable frequency value, for which the input voltage value has been assumed $U(\text{jo}) = 1$ V.

Parameters of the primary and secondary side of the transformer have been determined according to the procedure diagram [8] and were respectively: $\beta_1 = 0.503$, $L_{p1} = 8.813$ mH·s$^{(1-\gamma)}$, $\beta_2 = 0.502$, $L_{p2} = 3.113$ mH·s$^{(1-\gamma)}$. For two capacitors with known capacitances $C_1 = 10$ mF, $C_2 = 3.53$ mF in the investigated circuit, as in Fig. 1, two values of resonance frequencies $f_1 = 100$ Hz, $f_2 = 200$ Hz have been recorded. From the dependencies (4) and (5), the searched values of the fractional-order parameters of the mutual inductance have been determined:

$$\gamma = 0.503$$

and:

$$M_\gamma = 1.554$$

### 4 Summary

The paper proposes a modified method, compared to the method presented in [8], for identifying $M_\gamma, \gamma$ parameters of a fractional-order transformer. This method is based on the measurement of the phase resonance frequency in a circuit containing the analyzed transformer and two switchable standard capacitors. The dependencies allowing the determination of the fractional-order mutual inductance parameters have been given, on the basis of the described measurements.

The advantage of the modified method for determining the fractional-order parameters is the fact, that only one series opposite-aiding connection of the fractional-order coupled coils is enough to determine the searched parameters. The need to measure the input impedance of the circuit from Fig. 1 is also avoided.

### References

7. P. Xia, S. Liang, 1st Int. Conf. on Inf. Tech., Inf. Sys. and El. Eng. (ICITISEE), 31-36 (Yogyakarta, Indonesia, 2016)