UDK 621.373 – 187.4

N.I. Tverdostup

SYNTHESIS OF HARMONIC TRANSFORMER OF INDUCTIVE IMPEDANCE ON THE BASIS OF THE COMBINED OPERATING-ROOM OF CHART

On the basis of the generalized model of transformers of impedance F is synthesized is a metrical transformer of inductance in frequency of harmonic vibrations, for that there is not fundamental limitation of sensitiveness to variation of inductance.

Keywords: synthesis, inductive impedance, harmonious transformer, operating chart, feed-back, F is a meter.

Introduction. An actual task is creation of functional units for a receipt and roughing-out of information from measuring sensors. Expedient for the decision of this task is the use of transformers of impedance [1], development of that, on the requirements of certain task, is substantially simplified at presence of their base model. In [2] the brought generalized model over of transformers of impedance, what perspective for using as base at creation of various transformers.

Formulation of the problem. The aim of work is determination of possibilities of the use of the generalized model of transformers of impedance for the synthesis of harmonious transformer of inductive impedance.

Main part. The synthesis of harmonious transformer of inductive impedance will conduct based on the generalized model of transformers of impedance [2], what is given as an operating strengthener with the combined feed-back (Fig.1). Such linear combined operating chart (LCOS) has functionally a complete set of entrance impedance in a kind

$$\dot{Z}_{вх1} = (\dot{Z}_1 - \dot{Z}_2\dot{Z}_3/\dot{Z}_4)/(1-n), \qquad (1)$$

$$Z_{вх2} = (\dot{Z}_3 - \dot{Z}_1\dot{Z}_4/\dot{Z}_2)/(1-l), \qquad (2)$$

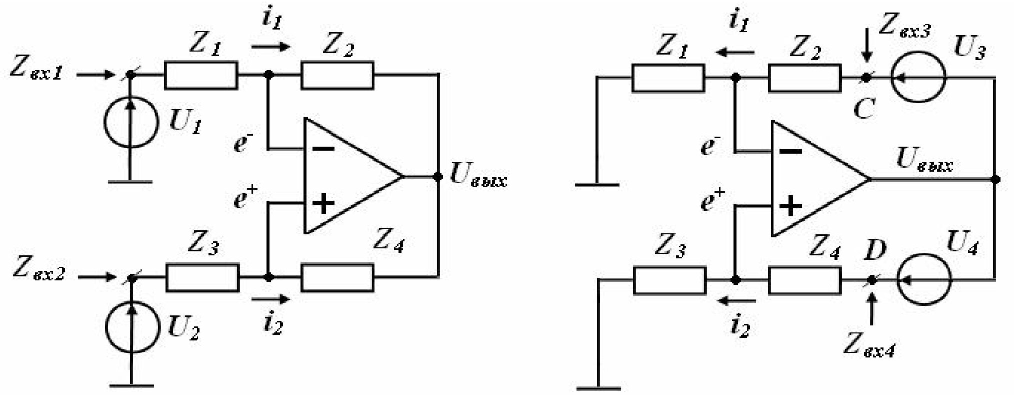
$$\dot{Z}_{вх3} = (\dot{Z}_2 - \dot{Z}_1\dot{Z}_4/\dot{Z}_3)/(1-k), \qquad (3)$$

$$\dot{Z}_{вх4} = (\dot{Z}_4 - \dot{Z}_2\dot{Z}_3/\dot{Z}_1)/(1-p), \qquad (4)$$

where $\dot{Z}_1$, $\dot{Z}_2$, $\dot{Z}_3$, $\dot{Z}_4$ – linear impedance of arbitrary character, U_1, U_2, U_3, U_4 – are sources of tension of excitation, $n = U_2/U_1$, $l = U_1/U_2$, $k = U_4/U_3$, $p = U_3/U_4$. Sizes and

---

signs of constituents of entrance impedance are determined by peak and phase between tensions of sources of excitation.



a) b)

Figure 1 – Is the Linear combined operating chart (LCOS) with the earthed (a) and self-weighted (b) sources of tension of excitation

For impedance $\dot{Z}_{вх1}$ at common-mode voltages U_1 and U_2 $n > 0$. Choosing $Z_1 = 0$ and $0 < n < 1$ we get that $\dot{Z}_{вх1} = -\dot{Z}_2\dot{Z}_3/\dot{Z}_4/(1-n)$. It follows that the LCOS converts the impedances Z_2 and Z_3 by changing their values and signs, that is, it acts as a negative impedance converter (CNI). Impedance Z_4 converts the circuit by changing its value, character and character, so, relative to Z_4, the LCOS is a negative impedance inverter (INI). If $Z_1 = 0$ and $n > 1$, the input impedance of the LCOS is positive $Z_{вх1} > 0$; in this case, the circuit converts the impedances Z_2, Z_3 with a change in their values and the preservation of the characters, that is, it acts as a positive impedance converter (CPI). Impedance Z_4 is transformed with a change in the nature of the magnitude and preservation of the sign, that is, with respect to Z_4, LCOS is a positive impedance inverter (IPI).

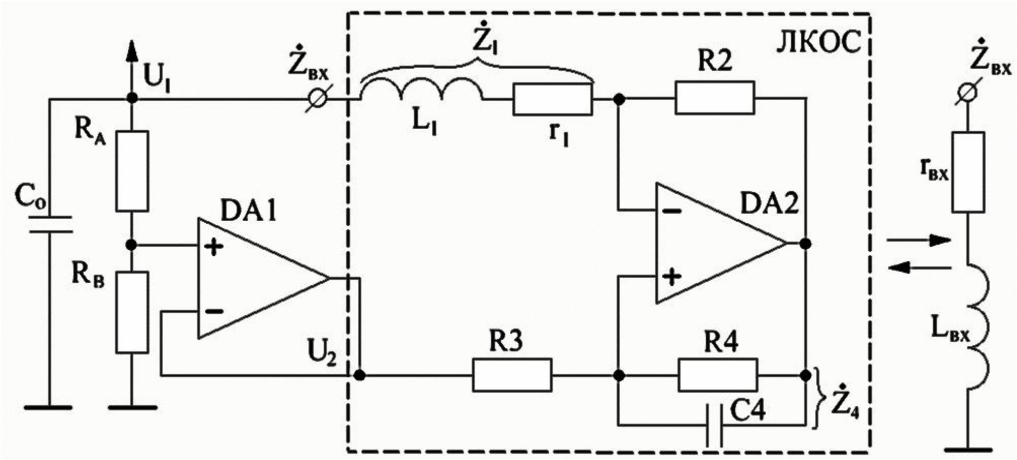
For $Z_1 \neq 0$, $Z_4 = \infty$ (or $Z_2 = Z_3 = 0$) and $0 < n < 1$, the input impedance is $\dot{Z}_{вх1} = \dot{Z}_1/(1-n)$, so, as for Z_1, LCOS is a CPI with transmission coefficient, which depends on the value of n. In case $n > 1$, the input impedance becomes negative $Z_{вх1} < 0$ and the circuit turns into the CNI.

A similar analysis $\dot{Z}_{вх2}$, $\dot{Z}_{вх3}$, $\dot{Z}_{вх4}$ gives similar results to the previous one, indicating the possibility of synthesis of various impedance converters based on a generalized model in the form of LCOS.

Let's consider the synthesis based on the LCOS F-metric converter of the inductance of some passive sensor. The F-meter method is convenient for coordination with computer processing devices, but it has a fundamental disadvantage – low and limited sensitivity to the measured parameter. The latter substantiates the relevance of such a synthesis problem.

The measuring generator (Fig. 2) is created based on LCOS, in which the input impedance according to (1) is equal to

$$\dot{Z}_{вх} = (\dot{Z}_1 - R_2R_3/\dot{Z}_4)/(1-n), \tag{5}$$



a) b)

Figure 2 - Measuring oscillator based on LCOS (a);
equivalent representation of the input impedance of LCOS (b)

where $\dot{Z}_1 = r_1 + j\omega L_1$- complex impedance of the sensor with an inductance L_1 and an active resistance r_1; R_2, R_3 – active supports of the circle of the combined backhaul of the amplifier DA2; $\dot{Z}_4 = R_4/(1 + j\omega C_4R_4)$ – is a complex impedance parallel to the connected resistance R_4 and the capacitance C_4. Repeater for amplifiers DA1 with resistive divider R_A, R_B is the source of excitation voltage U_2, common-mode source of input voltage U_1. The relation n for this case has the form $n = R_B/(R_A + R_B)$. Under these conditions, the input impedance of LCOS equals

$$\dot{Z}_{вх} = (1 + R_B/R_A)(r_1 + j\omega L_1 - R_2R_3/R_4 - j\omega C_4R_2R_3). \tag{6}$$

From (6), expressions of active $r_{вх}$ and inductive $L_{вх}$ components of the input impedance $\dot{Z}_{вх}$

$$r_{вх} = (1 + R_B/R_A)(r_1 - R_2R_3/R_4), \tag{7}$$

$$L_{вх} = (1 + R_B/R_A)(L_1 - C_4R_2R_3), \tag{8}$$

which indicate that the inductance L_1 and the active resistance r of the sensor are converted to the input inductance $L_{вх}$ and the resistance $r_{вх}$ with the multiplication factor $m = (1 + R_B/R_A)$.

It follows from (7) that multiplication of the resistance r1 is accompanied by its compensation by the negative active component of the input impedance of the LCOS, which is equal to $R_{(-)} = -R_2R_3/R_4$, and with $R_{(-)} \to$ r1 the input resistance $r_{вх} \to 0$, which indicates the possibility of a significant increase in the quality of the input inductance. It follows from (8) that the multiplication of the inductance L1 by the coefficient m occurs simultaneously with the decrease of its value by the value $C_4R_2R_3$, which in the future we will call the compensating inductance Lк.

Assume that under the influence of the measured parameter, the inductance L1 varies by a value of ΔL1, then the input inductance of LCOS becomes equal

$$L_{вх} + \Delta L_{вх} = m(L_1 + \Delta L_1 - L_к). \tag{9}$$

It follows from (8) and (9) that the absolute and relative increase in the input inductance are $\Delta L_{вх} = m\Delta L_1$ and $\Delta L_{вх}/L_{вх} = \Delta L_1/(L_1 - L_к)$, and with $L_к \to L_1$ $\Delta L_{вх}/L_{вх} \to \infty$. It is seen that the absolute increase in $\Delta L_{вх}$ is determined by the multiplication factor *m*, and the relative $\Delta L_{вх}/L_{вх}$ – the value of the compensating inductor $L_к$. This shows that in LCOS the scale of the inductor of the sensor and the control of the sensitivity to the measured parameter are realized.

A capacitance C_o is connected to the LCOS input, which, in conjunction with the input inductance $L_{ВХ}$, forms an oscillatory circuit. From (7) it turns out that under the condition r1 < R_2R_3/R_4 in the circuit there is a negative active component of the LCOS input resistance, which compensates for the active losses in the circuit and provides stationary harmonic oscillations at the resonance frequency

$$f = \frac{1}{2\pi\sqrt{m(L_1 - L_к)C_o}}. \tag{10}$$

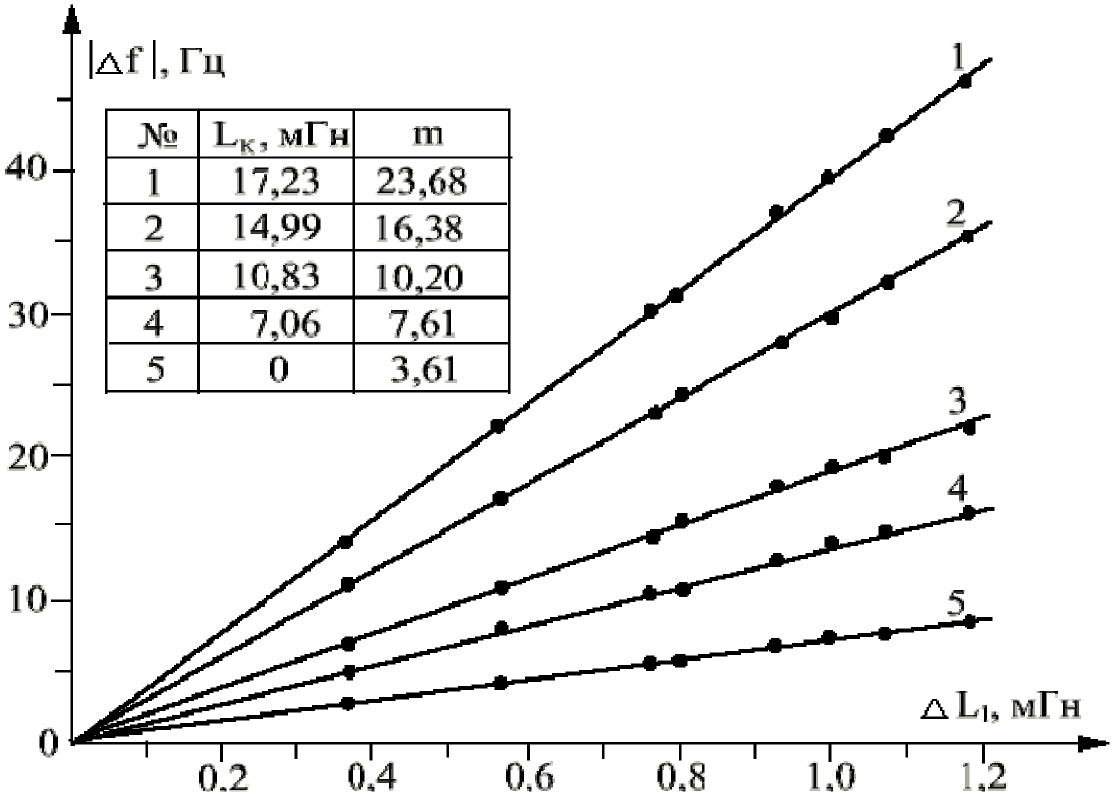
When the magnitude of the inductor L_1 of the sensor is changed, the frequency increment is

$$\Delta f = \frac{df}{dL_{вх}}\Delta L_{вх} = -\frac{1}{4\pi\sqrt{m(L_1 - L_к)C_o}} \cdot \frac{\Delta L_1}{(L_1 - L_к)}. \tag{11}$$

It can be seen from (11) that the increase in frequency is significantly increased with $L_к \to L_1$. This substantiates the possibility of significantly increasing the sensitivity of the *F*-meter on the basis of the LCOS to the change of the inductor L_1 of the parametric sensor.

The experimental verification of expression (11) was carried out on the measuring generator (Fig. 2), which was assembled on the ICL7650 operative amplifiers with an inductance L_1 = 21 mH, with a capacity C_o = 1,106 μF and an initial oscillation frequency of 460 Hz. In Figure 3 shows the experimental dependencies of the module for increasing the frequency Δ*f* of the generator from an increase in the inductor ΔL_1 of the sensor at a variation of the values of compensating inductance

$L_к$ from 0 to 17.23 mH. It is evident that with the value $L_к$ = 0 (dependence 5), the sensitivity to ΔL_1 is minimal and is 7.5 Hz/mH, while the magnitude $L_к$ of the sensitivity increases, with $L_к$ = 17.23 mH (dependence 1) the sensitivity increases by five times to 39.2 Hz/mH. This confirms that the magnitude of the compensating inductance $L_к$ can be controlled by the sensitivity of the measuring generator within the conditions of the condition $L_1 - L_к > 0$. The calculation dependence (11) is in good agreement with the experimental data, the difference does not exceed 5%.



№	$L_К$, мГн	m
1	17,23	23,68
2	14,99	16,38
3	10,83	10,20
4	7,06	7,61
5	0	3,61

Figure 3 – Increase the generator frequency Δf as a function increase ΔL_1 inductor of the sensor

Conclusions. The result of the analysis is as follows:

– synthesis based on LCOS has allowed to create a measuring device in the form of an *F*-meter, which, unlike the traditional method, does not have a fundamental limitation of sensitivity, and, sensitivity can be controlled by changing the multiplication factor and compensating inductance;

– a generalized model of impedance converters in the form of LCOS can be used as a basic scheme for the synthesis of harmonic converters inductive impedance.

REFERENCES

1. Филановский, И.М. Схемы с преобразователями сопротивления [Текст] / И.М. Филановский, А. Ю. Персианов, В.К. Рыбин – Л.: Энергия, 1973. – 192 с.

2. Твердоступ, Н.И. Обобщенная модель преобразователей импеданса [Текст] / Н.И. Твердоступ // Вісник Дніпропетр. ун-ту. Фізика. Радіоелектроніка. – 2010. – Вип. 17, №2. – С. 103 - 108.

REFERENCES

1. Fylanovskyi, Y.M. Skhemы s preobrazovateliamy soprotyvlenyia [Tekst] / Y.M. Fylanovskyi, A. Yu. Persyanov, V.K. Rыbyn – L.: Эnerhyia, 1973. – 192 s.

2. Tverdostup, N.Y. Obobshchennaia model preobrazovatelei ympedansa [Tekst] / N.Y. Tverdostup // Visnyk Dnipropetr. un-tu. Fizyka. Radioele-ktronika. – 2010. – Vyp. 17, №2. – S. 103 - 108.