**Mykoła HRYBOK**
LVIV POLYTECHNIC NATIONAL UNIVERSITY, DEPARTMENT OF INFORMATION-MEASURING TECHNOLOGY

# Measurement of complex resistance parameters by the method of coordinate system displacement on current

**Ph.D. Mykoła HRYBOK**

Has finished the Computer Technique Department of Lviv Polytechnic Ukraine) . Has gained the degree of doctor-engineer in Kyiv Polytechnic in 1983. The associated professor in Lviv Polytechnic. His scientific interest is related to the analysis and conversion of signals as well as synthesis of algorithmic ways of scalar and vector value measurement. The results of his scientific work make the basis for the projecting of the measurement computer systems.

*e-mail: Rossardy@yandex.ru*

**Abstract**

Possibility of complex resistance parameter measurement within a frequency range by the method of coordinate system displacement on current components is investigated.

**Keywords**: complex resistance parameter, measurement, calibration, algorithmic methods.

## Pomiary parametrów składowych impedancji metodą przesunięcia systemu współrzędnych według prądu

**Streszczenie**

W pracy zbadano możliwości pomiaru parametrów impedancji metodą przesunięcia systemu współrzędnych według prądu w wybranym zakresie częstotliwości.

**Słowa kluczowe**: parametry impedancji, mierniki, wzorcowanie, metody algorytmiczne.

## 1. Introduction

The necessity of complex resistance parameter determination within a frequency range arises in many areas of science and technique. The components of complex resistances frequently comply with the particular quality characteristics of a research object, therefore their measurement accuracy is a topical task.

**The analysis of previous development and existing literary sources.** The methods of equilibration (compensating or bridge ones [1, 2]) provide high metrological characteristics only on fixed frequencies, as a rule, 1 kHz. Analogous disadvantage is appropriate for means [7], in which the method of phase sensitive detection is realised. The implementation of calculating technique in measuring rings [4, 5, 6, 7, 8] has given new possibilities at complex resistance parameter measurement. The possibility of substitution method employment at RLC-parameter measurement is investigated in [5]. Although the possibility of the presence of aprior information about complex input phase measurer resistance, functioning voltage value measurer and high-precision phase measurer application within a frequency range contract the areas of application and lower potential measurement accuracy.

**Objective of research.** Accuracy increasing of complex resistance component measurement by the method of coordinate system displacement on current.

## 2. Measurement scheme on the basis of mathematical correlations

Complex resistance RLC-parameter measurement schemes are synthesized due to the methods of vector value parameter measurement [11, 12, 13] and the Ome's Law on AC (1):

$$\dot{Z} = \frac{\dot{U}}{\dot{I}}; \qquad \dot{g} = \frac{\dot{I}}{\dot{U}}. \tag{1}$$

A generalised structural measurement scheme (fig. 1) consists of sinusoid voltage source (SVS), commutator (C), control block (CB), analogue-to-digital converter (ADC) of a functioning voltage value, digital frequency meter (DFM), calculating device (CD), reference active resistances $R_{01}$, $R_{02}$, reference complex resistance $\dot{Z}_0$.

Voltage falling on resistor $R_{01}$ is proportional to the current value $I_1$. Voltage falling on resistor $R_{02}$ is proportional to the current value $I_2$. Due to reference complex resistance $\dot{Z}_0$ ($R_0$, $j\omega L_0$, $1/j\omega C_0$), current $i_{x0}=O_1O_2$ or $i_{y0}=O_1O_3$ will flow through $\dot{Z}_0$ [fig.2]. The values of synphase $i_x$ and quadruple $i_y$ current components in complex resistance $\dot{Z}$ are determined from the correlation (2) at $R_{01} << \left|\dot{Z}\right|$

$$i_x = \frac{i_2^2 - i_1^2 - i_{x0}^2}{2 i_{x0}}; \qquad i_y = \frac{i_2^2 - i_1^2 - i_{y0}^2}{2 i_{y0}}. \tag{2}$$

So long as $\dot{I}_{x0}=\dot{U}_{23}/R_0$; $\dot{I}_{y0}=\dot{U}_{23}/j\omega L_0$; $\dot{I}_{y0}=j\dot{U}_{23}\omega C_0$, then $g= i_x/U_{2'3}$, $b = i_y/U_{2'3}$, or $b=\sqrt{y^2-g^2}$.

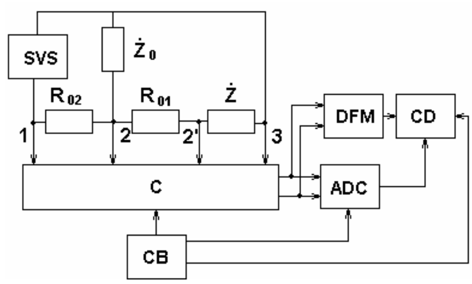



Fig. 1. Generalised structural scheme of complex resistance RLC-parameter measurer by the method of coordinate system displacement on current
Rys. 1. Schemat blokowy do pomiaru parametrów RLC impedancji metodą przesunięcia systemu współrzędnych według prądu

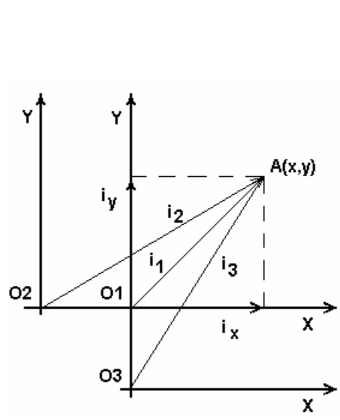



Fig. 2. Coordinate systems at the measurement of synphase and quadruple current components
Rys. 2. System współrzędnych przesunięty według prądu dla pomiarów składowych impedancji

At $R_{01} \approx |\dot{Z}|$ the considerable methodical error of the determination of g and b. The providing of $R_{01} << |\dot{Z}|$ is not always practically possible. The disadvantage of $R_{01} << |\dot{Z}|$ condition is the fact that voltage $U_{22'} << U_{2'3}$, and it means that a voltmeter will work within different measurement ranges at the determination of $U_{22'}$ and $U_{12}$, $U_{23}$ and $U_{2'3}$.This disadvantage could be replaced in the following way.

Let us express complex resistance $\dot{Z}$=r+jx through conductance $Y=\frac{r}{Z^2}-j\frac{x}{Z^2}$=g–jb. The resistance between the points 2 and 3 of right branch $\dot{Z}_1=\dot{Z}+R_{01}=(r+R_{01})+jx=r_1+jx_1$ could be expressed through conductance $\dot{Y}_1=\frac{r_1}{Z_1^2}-j\frac{x_1}{Z_1^2}=g_1-jb_1$. The synphase component $i_x$ of current, that flows through the conductance $g_1$, is equal to $i_x=\frac{i_2^2-i_1^2-i_{R0}^2}{2\,i_{R0}}$, where $i_2=\frac{U_{12}}{R_{02}}$; $i_1=\frac{U_{22'}}{R_{01}}$; $i_{R0}=\frac{U_{23}}{R_0}$. We can express conductance $g_1=\frac{i_x}{U_{23}}=\frac{r_1}{Z_1^2}$.

As a result $r_1=g_1*Z_1^2$ ; where $Z_1=\frac{U_{23}}{i_1}$.

Since the values of resistances $R_{01}$ and $R_{02}$ are known, we can receive the synphase $r=(r_1-R_{01})$ and a quadruple resistance component $\dot{Z}$ $x=\sqrt{Z_1^2-r_1^2}$. At this estimation of r and x the resistance value $R_{01}$ could be commensurable with the module of the complex resistance value $\dot{Z}$.

To determine the parameters $x_1$, $x_2$, $x_3$ of three-component complex resistances on the two frequencies $\omega_1$ and $\omega_2$ Re $\dot{Z}$ ($\omega_1$, $x_1$, $x_2$, $x_3$), Re $\dot{Z}$ ($\omega_2$, $x_1$, $x_2$, $x_3$), Im $\dot{Z}$ ($\omega_1$, $x_1$, $x_2$, $x_3$) and Im $\dot{Z}$ ($\omega_2$, $x_1$, $x_2$, $x_3$) are being determined. The solution of equation system [15] (3)

$$\begin{aligned} N_{11} &= \mathrm{Re}\ \dot{Z}\ (\omega_1, x_1, x_2, x_3) \\ N_{12} &= \mathrm{Im}\ \dot{Z}\ (\omega_1, x_1, x_2, x_3) \\ N_{21} &= \mathrm{Re}\ \dot{Z}\ (\omega_2, x_1, x_2, x_3) \\ N_{22} &= \mathrm{Im}\ \dot{Z}\ (\omega_2, x_1, x_2, x_3) \end{aligned} \quad (3)$$

determines the values $x_1$, $x_2$, $x_3$.

## 3. Determination of the RLC-parameters of three-component complex resistances

Due to the principles of the method of coordinate system displacement on current at the measurement of complex resistance parameters, the generalised structural scheme of the measuring ring is being synthesized. In which an object of research as three-component complex resistance ThCR is expressed as $\dot{Z}$. Due to a configuration scheme, a ThCR mathematical model could be presented as the complex resistance $\dot{Z}$ or the complex conductance $\dot{Y}$. If it is easier to describe ThCR mathematically as conductance, then in the consequence of the expression Y=g–jb we immediately receive the resistance expression: $\dot{Z}$= r+jx $=\frac{g}{Y^2}+j\frac{b}{Y^2}$.

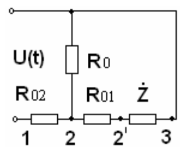


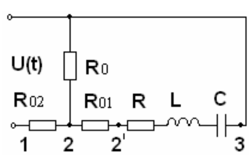

Fig. 3. Generalised scheme of a measuring ring
Rys. 3. Schemat ogólny obwodu pomiarowego

So long as measurement is being conducted on the two frequencies, we receive an equation system according to consequent and parallel RLC-schemes:

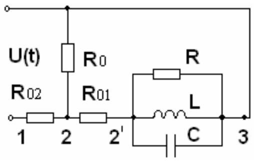
$$\dot{Z}_1=r_1+jx_1;$$
$$\dot{Z}_2=r_2+jx_2;$$
$$\dot{Z}_3=(r_1+R_{01})+jx_1;$$
$$\dot{Z}_4=(r_2+R_{01})+j\,x_2.$$
$$\dot{Y}_1=g_1-jb_1;$$
$$\dot{Y}_2=g_2-jb_2;$$
$$\dot{Z}_1=r_1+jx_1=\frac{g_1}{Y_1^2}+j\frac{b_1}{Y_1^2};$$
$$\dot{Z}_2=r_2+jx_2=\frac{g_2}{Y_2^2}+j\frac{b_2}{Y_2^2};$$
$$\dot{Z}_3=(r_1+R_{01})+jx_1;$$
$$\dot{Z}_4=(r_2+R_{01})+jx_2.$$

Thus, due to the chosen $R_0$, $f_1$, $f_2$ and the measured voltage values $U_{12}$, $U_{23}$, $U_{22'}$ , it is possible to determine $Z_1$, $Z_2$, $Z_3$, $Z_4$, $r_1$, $r_2$, $x_1$, $x_2$, $Y_1$, $Y_2$, $g_1$, $g_2$, $b_1$ and $b_2$. These values to some extent are sufficient to determine ThCR RLC-parameters of any configuration (table 1). The results of measurement do not depend on the coefficient value of the ADC transmission of alternating voltage into a code. Its stability is required only for the time of RLC-parameter determination.

Tab. 1. Measuring ring scheme and major mathematical correlations
Tab. 1. Schematy pomiarowe i podstawowe zależności matematyczne

| № | Measuring ring scheme and major mathematical correlations |
|---|---|
| 1 |   $\dot{Z}_1=R+j\,(\omega_1 L-\frac{1}{\omega_1 C})=r_1+j\,x_1;$ <br> $\dot{Z}_2=R+j\,(\omega_2 L-\frac{1}{\omega_2 C})=r_2+j\,x_2;$ <br> $\dot{Z}_3=(R+R_{01})+j(\omega_1 L-\frac{1}{\omega_1 C})=(R_{01}+r_1)+j\,x_1;$ <br> $\dot{Z}_4=(R+R_{01})+j(\omega_2 L-\frac{1}{\omega_2 C})=(R_{01}+r_2)+j\,x_2;$ <br> $C=\frac{\omega_1^2-\omega_2^2}{\omega_1\omega_2(x_1\omega_2-x_2\omega_1)}$; $L=\frac{x_2\omega_2-x_1\omega_1}{\omega_2^2-\omega_1^2}$; $R=\sqrt{Z_1^2-X_1^2}$; |

2




$\dot Y_1=\frac{1}{R}-j(\frac{1}{\omega_1 L}-\omega_1 C)=g_1-j\,b_1;$

$\dot Y_2=\frac{1}{R}-j(\frac{1}{\omega_2 L}-\omega_2 C)=g_2-j\,b_2;$

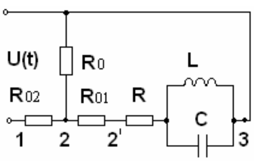
$\dot Z_1=r_1+j\,x_1=\frac{g_1}{Y_1^2}+j\frac{b_1}{Y_1^2};\ \dot Z_3=(r_1+R_{01})+j\,x_1;$

$\dot Z_2=r_2+j\,x_2=\frac{g_2}{Y_2^2}+j\frac{b_2}{Y_2^2};\ \dot Z_4=(r_2+R_{01})+j\,x_2;$

$R=r_1 Y_1^2;$

$C=\frac{b_1\omega_1-b_2\omega_2}{\omega_2^2-\omega_1^2};\ L=\frac{\omega_1^2-\omega_2^2}{\omega_1\omega_2(b_1\omega_2-b_2\omega_1)}$

3




$\dot Z_1=R+j(\frac{\omega_1 L}{1-\omega_1^2 L\,C})=r_1+j\,x_1;$

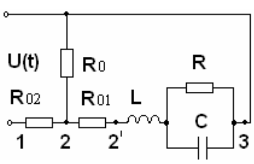
$\dot Z_2=R+j(\frac{\omega_2 L}{1-\omega_2^2 L\,C})=r_2+j\,x_2;$

$\dot Z_3=(r_1+R_{01})+j\,x_1;\ \dot Z_4=(r_2+R_{01})+j\,x_2;$

$C=\frac{x_2\omega_1-x_1\omega_2}{x_1x_2(\omega_2^2-\omega_1^2)};\ L=\frac{x_1x_2(\omega_2^2-\omega_1^2)}{\omega_1\omega_2(x_2\omega_2-x_1\omega_1)};$

$R=\sqrt{Z_1^2-X_1^2}$

4




$\dot Z_1=\frac{R}{1+\omega_1^2C^2R^2}+j(\omega_1 L-\frac{R^2\omega_1 C}{1+\omega_1^2C^2R^2})=$

$=r_1+j\,x_1;$

$\dot Z_2=\frac{R}{1+\omega_2^2C^2R^2}+j(\omega_2 L-\frac{R^2\omega_2 C}{1+\omega_2^2C^2R^2})=$

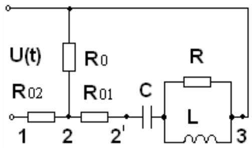
$=r_2+j\,x_2;$

$\dot Z_3=(r_1+R_{01})+j\,x_1;\ \dot Z_4=(r_2+R_{01})+j\,x_2;$

$C=\frac{1}{\omega_1 R}\sqrt{\frac{R-r_1}{r_1}};\ L=\frac{x_1+r_1R\,\omega_1 C}{\omega_1};$

$R=\frac{r_1r_2(\omega_2^2-\omega_1^2)}{(r_2\omega_2^2-r_1\omega_1^2)}$

5



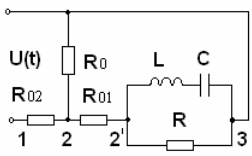

$\dot Z_1=\frac{R\,\omega_1^2L^2}{R^2+\omega_1^2L^2}+j\left[\frac{R^2\omega_1 L}{R^2+\omega_1^2L^2}-\frac{1}{\omega_1 C}\right]=r_1+jx_1;$

$\dot Z_2=\frac{R\,\omega_2^2L^2}{R^2+\omega_2^2L^2}+j\left[\frac{R^2\omega_2 L}{R^2+\omega_2^2L^2}-\frac{1}{\omega_2 C}\right]=r_2+jx_2;$

$\dot Z_3=(r_1+R_{01})+j\,x_1;\ \dot Z_4=(r_2+R_{01})+j\,x_2;$

$L=\frac{R}{\omega_1}\sqrt{\frac{r_1}{R-r_1}};\ C=\frac{1}{\frac{r_1R}{L}-\omega_1x_1};\ R=\frac{r_1r_2(\omega_2^2-\omega_1^2)}{(r_1\omega_2^2-r_2\omega_1^2)}$

6




$\dot Y_1=\frac{1}{R}-j(\frac{1}{\omega_1 L-\frac{1}{\omega_1 C}})=g_1-j\,b_1;$

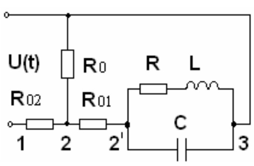
$\dot Y_2=\frac{1}{R}-j(\frac{1}{\omega_2 L-\frac{1}{\omega_2 C}})=g_2-j\,b_2;$

$\dot Z_1=\frac{g_1}{Y_1^2}+j\frac{b_1}{Y_1^2}=r_1+j\,x_1;\ \dot Z_3=(r_1+R_{01})+j\,x_1;$

$\dot Z_2=\frac{g_2}{Y_2^2}+j\frac{b_2}{Y_2^2}=r_2+j\,x_2;\ \dot Z_4=(r_2+R_{01})+j\,x_2;$

$R=\frac{1}{r_1Y_1^2};\ L=\frac{b_1\omega_2-b_2\omega_1}{b_1b_2(\omega_2^2-\omega_1^2)};\ C=\frac{b_1b_2(\omega_2^2-\omega_1^2)}{\omega_1\omega_2(b_1\omega_1-b_2\omega_2)};$

7




$\dot Y_1=\frac{R}{R^2+\omega_1^2L^2}+j\left[\frac{\omega_1 L}{R^2+\omega_1^2L^2}-\omega_1 C\right]=g_1-jb_1;$

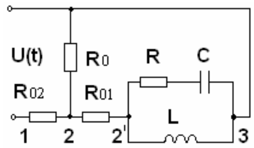
$\dot Y_2=\frac{R}{R^2+\omega_2^2L^2}+j\left[\frac{\omega_2 L}{R^2+\omega_2^2L^2}-\omega_2 C\right]=g_2-jb_2;$

$\dot Z_1=r_1+j\,x_1=\frac{g_1}{Y_1^2}+j\frac{b_1}{Y_1^2};\ \dot Z_3=(r_1+R_{01})+j\,x_1;$

$\dot Z_2=r_2+j\,x_2=\frac{g_2}{Y_2^2}+j\frac{b_2}{Y_2^2};\ \dot Z_4=(r_2+R_{01})+j\,x_2;$

$R=\frac{g_2\omega_2^2-g_1\omega_1^2}{g_1g_2(\omega_2^2-\omega_1^2)};\ L=\frac{1}{\omega_1}\sqrt{\frac{R-g_1R^2}{g_1}};\ C=\frac{b_1+\frac{g_1\omega_1 L}{R}}{\omega_1};$

**8**




$$\dot{Y}_1=\frac{R\,\omega_1^2C^2}{1+\omega_1^2C^2R^2}-j\left[\frac{1}{\omega_1 L}-\frac{\omega_1 C}{1+\omega_1^2C^2R^2}\right]= g_1 - j\,b_1;$$

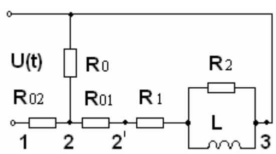
$$\dot{Y}_2=\frac{R\,\omega_2^2C^2}{1+\omega_2^2C^2R^2}-j\left[\frac{1}{\omega_2 L}-\frac{\omega_2 C}{1+\omega_2^2C^2R^2}\right]= g_2 - j\,b_2;$$

$$\dot{Z}_1=r_1+j\,x_1=\frac{g_1}{Y_1^2}+j\frac{b_1}{Y_1^2};\ \dot{Z}_3=(r_1+R_{01})+j\,x_1;$$

$$\dot{Z}_2=r_2+j\,x_2=\frac{g_2}{Y_2^2}+j\frac{b_2}{Y_2^2};\ \dot{Z}_4=(r_2+R_{01})+j\,x_2;$$

$$R=\frac{g_1\omega_2^2-g_2\omega_1^2}{g_1g_2(\omega_2^2-\omega_1^2)};\ L=\frac{1}{\frac{g_1}{R\,C}+b_1\omega_1};\ C=\frac{1}{\omega_1}\sqrt{\frac{g_1}{R-g_1R^2}}$$

**9**




$$\dot{Z}_1=\left[R_1+\frac{R_2\omega_1^2L^2}{R_2^2+\omega_1^2L^2}\right]+j\frac{R_2\omega_1 L}{R_2^2+\omega_1^2L^2}= r_1+j\,x_1;$$

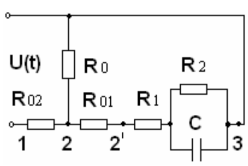
$$\dot{Z}_2=\left[R_1+\frac{R_2\omega_2^2L^2}{R_2^2+\omega_2^2L^2}\right]+j\frac{R_2\omega_2 L}{R_2^2+\omega_2^2L^2}= r_2+j\,x_2;$$

$$\dot{Z}_3=(r_1+R_{01})+j\,x_1;\ \dot{Z}_4=(r_2+R_{01})+j\,x_2;$$

$$L=\frac{x_1x_2(\omega_2^2-\omega_1^2)}{\omega_1\omega_2\left(x_2\omega_2-x_1\omega_1\right)};$$

$$R_2=\omega_1 L\sqrt{\frac{x_1}{\omega_1 L-x_1}};\ \ R_1=r_1-\frac{x_1\omega_1 L}{R_2}$$

**10**




$$\dot{Z}_1=\left[R_1+\frac{R_2}{1+R_2^2\omega_1^2C^2}\right]-j\frac{R_2^2\omega_1 C}{1+R_2^2\omega_1^2C^2}=r_1+j\,x_1;$$

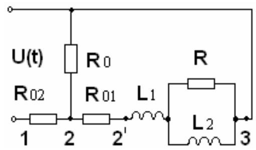
$$\dot{Z}_2=\left[R_1+\frac{R_2}{1+R_2^2\omega_2^2C^2}\right]-j\frac{R_2^2\omega_2 C}{1+R_2^2\omega_2^2C^2}=r_2+j\,x_2;$$

$$\dot{Z}_3=(r_1+R_{01})+j\,x_1;\ \dot{Z}_4=(r_2+R_{01})+j\,x_2;$$

$$C=\frac{x_1\omega_2-x_2\omega_1}{x_1x_2(\omega_2^2-\omega_1^2)};$$

$$R_2=\sqrt{\frac{x_1}{\omega_1 C\,(1-x_1\omega_1 C)}};\ R_1=r_1-\frac{x_1}{R_2\omega_1 C}$$

**11**



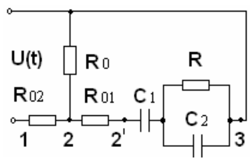

$$\dot{Z}_1=\frac{R\,\omega_1^2L_2^2}{R^2+\omega_1^2L_2^2}+j\left[\frac{R^2\omega_1L_2}{R^2+\omega_1^2L_2^2}+\omega_1L_1\right]=r_1+j\,x_1;$$

$$\dot{Z}_2=\frac{R\,\omega_2^2L_2^2}{R^2+\omega_2^2L_2^2}+j\left[\frac{R^2\omega_2L_2}{R^2+\omega_2^2L_2^2}+\omega_2L_1\right]=r_2+j\,x_2;$$

$$\dot{Z}_3=(r_1+R_{01})+j\,x_1;\ \dot{Z}_4=(r_2+R_{01})+j\,x_2;$$

$$R=\frac{r_1r_2(\omega_2^2-\omega_1^2)}{r_1\omega_2^2-r_2\omega_1^2};\ L_2=\frac{R}{\omega_1}\sqrt{\frac{r_1}{R-r_1}};\ L_1=\frac{x_1-\frac{r_1R}{\omega_1L_2}}{\omega_1};$$

**12**




$$\dot{Z}_1=\frac{R}{1+R^2\omega_1^2C_2^2}-j\left[\frac{R^2\omega_1C_2}{1+R^2\omega_1^2C_2^2}+\frac{1}{\omega_1C_1}\right]= r_1+j\,x_1;$$

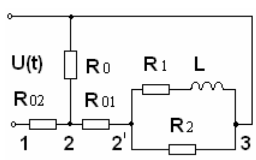
$$\dot{Z}_2=\frac{R}{1+R^2\omega_2^2C_2^2}-j\left[\frac{R^2\omega_2C_2}{1+R^2\omega_2^2C_2^2}+\frac{1}{\omega_2C_1}\right]= r_2+j\,x_2;$$

$$\dot{Z}_3=(r_1+R_{01})+j\,x_1;\ \dot{Z}_4=(r_2+R_{01})+j\,x_2;$$

$$C_2=\frac{1}{R\,\omega_1}\sqrt{\frac{R-r_1}{r_1}};\ C_1=\frac{1}{\omega_1\left(x_1-r_1R\,\omega_1C_2\right)}$$

$$R=\frac{r_1r_2(\omega_2^2-\omega_1^2)}{r_2\omega_2^2-r_1\omega_1^2}$$

**13**




$$\dot{Y}_1=\left[\frac{1}{R_2}+\frac{R_1}{R_1^2+\omega_1^2L^2}\right]-j\frac{\omega_1L}{R_1^2+\omega_1^2L^2}=g_1-j\,b_1;$$

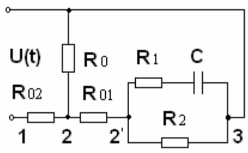
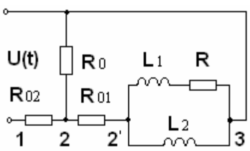
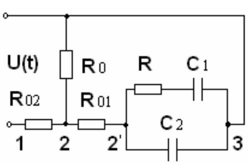
$$\dot{Y}_2=\left[\frac{1}{R_2}+\frac{R_1}{R_1^2+\omega_2^2L^2}\right]-j\frac{\omega_2L}{R_1^2+\omega_2^2L^2}=g_2-j\,b_2;$$

$$\dot{Z}_1=r_1+j\,x_1=\frac{g_1}{Y_1^2}+j\frac{b_1}{Y_1^2};\ \dot{Z}_3=(r_1+R_{01})+j\,x_1;$$

$$\dot{Z}_2=r_2+j\,x_2=\frac{g_2}{Y_2^2}+j\frac{b_2}{Y_2^2};\ \dot{Z}_4=(r_2+R_{01})+j\,x_2;$$

$$L=\frac{b_1\omega_2-b_2\omega_1}{b_1b_2(\omega_2^2-\omega_1^2)};\ R_2=\frac{1}{g_1-\frac{b_1R_1}{L\,\omega_1}};$$

$$R_1=\sqrt{\frac{\omega_1L\,(1-b_1\omega_1L)}{b_1}}$$

| | |
|---|---|
| 14 | <br><br>$\dot{Y}_1=\left[\frac{1}{R_2}+\frac{R_1\omega_1^2C^2}{1+R_1^2\omega_1^2C^2}\right]-j\frac{\omega_1 C}{1+R_1^2\omega_1^2C^2}=g_1-jb_1;$<br>$\dot{Y}_2=\left[\frac{1}{R_2}+\frac{R_1\omega_2^2C^2}{1+R_1^2\omega_2^2C^2}\right]-j\frac{\omega_2 C}{1+R_1^2\omega_2^2C^2}=g_2-jb_2;$<br>$\dot{Z}_1=r_1+j\,x_1=\frac{g_1}{Y_1^2}+j\frac{b_1}{Y_1^2};\ \dot{Z}_3=(r_1+R_{01})+j\,x_1;$<br>$\dot{Z}_2=r_2+j\,x_2=\frac{g_2}{Y_2^2}+j\frac{b_2}{Y_2^2};\ \dot{Z}_4=(r_2+R_{01})+j\,x_2;$<br>$C=\frac{b_1b_2(\omega_2^2-\omega_1^2)}{\omega_1\omega_2(b_2\omega_2-b_1\omega_1)};$<br>$R_1=\frac{1}{C\,\omega_1}\sqrt{\frac{C\,\omega_1-b_1}{b_1}};\ R_2=\frac{1}{(g_1-b_1R_1\omega_1C)}$ |
| 15 | <br><br>$\dot{Y}_1=\frac{R}{R^2+\omega_1^2L_1^2}-j\left[\frac{\omega_1L_1}{R^2+\omega_1^2L_1^2}+\frac{1}{\omega_1L_2}\right]=g_1-j\,b_1;$<br>$\dot{Y}_2=\frac{R}{R^2+\omega_2^2L_1^2}-j\left[\frac{\omega_2L_1}{R^2+\omega_2^2L_1^2}+\frac{1}{\omega_2L_2}\right]=g_2-j\,b_2;$<br>$\dot{Z}_1=r_1+j\,x_1=\frac{g_1}{Y_1^2}+j\frac{b_1}{Y_1^2};\ \dot{Z}_3=(r_1+R_{01})+j\,x_1;$<br>$\dot{Z}_2=r_2+j\,x_2=\frac{g_2}{Y_2^2}+j\frac{b_2}{Y_2^2};\ \dot{Z}_4=(r_2+R_{01})+j\,x_2;$<br>$R=\frac{g_2\omega_2^2-g_1\omega_1^2}{g_1g_2(\omega_2^2-\omega_1^2)};\ L_2=\frac{1}{\omega_1\left(b_1-\frac{g_1\omega_1L_1}{R}\right)};\ L_1=\sqrt{\frac{R-g_1R^2}{g_1\omega_1^2}};$ |
| 16 | <br><br>$\dot{Y}_1=\frac{R\,\omega_1^2C_1^2}{1+R^2\omega_1^2C_1^2}-j\left[\frac{\omega_1C_1}{1+R^2\omega_1^2C_1^2}+\omega_1C_2\right]=g_1-j\,b_1;$<br>$\dot{Y}_2=\frac{R\,\omega_2^2C_1^2}{1+R^2\omega_2^2C_1^2}-j\left[\frac{\omega_2C_1}{1+R^2\omega_2^2C_1^2}+\omega_2C_2\right]=g_2-j\,b_2;$<br>$\dot{Z}_1=r_1+j\,x_1=\frac{g_1}{Y_1^2}+j\frac{b_1}{Y_1^2};\ \dot{Z}_3=(r_1+R_{01})+j\,x_1;$<br>$\dot{Z}_2=r_2+j\,x_2=\frac{g_2}{Y_2^2}+j\frac{b_2}{Y_2^2};\ \dot{Z}_4=(r_2+R_{01})+j\,x_2;$<br>$C_1=\frac{1}{\omega_1}\sqrt{\frac{g_1}{R-g_1R^2}};\ C_2=\frac{b_1-\frac{g_1}{R\,\omega_1C_1}}{\omega_1};\ R=\frac{g_1\omega_2^2-g_2\omega_1^2}{g_1g_2(\omega_2^2-\omega_1^2)}$ |

## 4. Conclusions

The results of RLC-parameter measurement by the method of coordinate system displacement on current are independent of an ADC transmission coefficient value that is especially important at measurement conduction within the range of frequencies. A RLC-parameter measurement error to a great extent is determined from the correlation of g and b and commensurability of $1/R_0$ and g, as well as $\omega C_0$ and b along with ADC decimal gradation. At the absence of aprior information about values g i b it is expediently to conduct test measurement on purpose to specify the values $1/R_0$ and $\omega C_0$. At the considerable difference of g and b it is needed to change frequency ω at which g≈b.

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*Artykuł recenzowany*