Graphical-analytical method for constructing load characteristics

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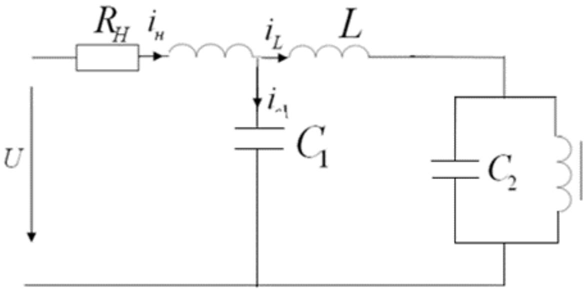
Abstract. The article discusses a graphical-analytical method for constructing the load characteristics of a three-element resonant circuit in the current stabilization mode. The current stabilization mode is observed when compensating the negative section of the S-shaped characteristics of the parallel resonant circuit of the connected sequence with a linear inductance and with a linear capacitor characteristic. The equation of the load mode in a dimensionless form represents the equation of an ellipse, which makes it possible to construct the necessary characteristics of a three-element resonant circuit for various types of load.

In engineering practice, various graphical methods for analyzing the operation of ferromagnetic devices have been applied. A graphical method is proposed for calculating the equivalent circuit of a three-element resonant circuit proposed in Fig. 1 in the current stabilization mode for a complex load.



In this case, the known current-voltage characteristic of the device for the unloaded mode and the currents of the branches of the circuit is assumed to be sinusoidal. [1-8] For the current stabilization mode with active-inductive load, the following equation is valid:

$$u=L_{н}\frac{di_c}{dt}+i_cR_{н}+u_c \qquad (1)$$

For active-capacitive load

$$u=\frac{1}{c}\int i_c dt+i_cR_{н}+u_c \qquad (2)$$

here: $L_{н}$, C, R_c, respectively, inductance, capacitance and active load resistance;

i_c- stabilization current;

u_c -voltage at the terminals of the three-element resonant circuit;

u -mains voltage;

Accept $i_c=I_{cm}\sin\omega t$, $u_c=U_{cm}\cos\omega t$; $u=U_m\cos(\omega t+\psi)$

Such an assumption is possible if the losses in the circuit of the circuit are neglected and provided that the circuit of the device operates in a capacitive mode. After some transformations and introduction of normalized values from (1) we get:

$$y_m^2=(\gamma Z_m-y_{cm})^2+\delta^2\beta_1^2Z_m^2, \qquad (3)$$

Where

$$\gamma=\frac{L_{н}}{L};\delta=\omega C_1R_{н};\beta_1=\frac{1}{\omega^2LC_1};y_{cm}=\frac{u_{cm}}{U_\delta};Z_m=\frac{I_m}{i_\delta};y_m=\frac{u_m}{U_\delta}.$$

For the case of active-capacitive load

$$y_m^2=(\gamma_c Z_m+y_{cm})^2+\delta^2\beta_1Z_m^2 \qquad (4)$$

Here $\gamma_c=\frac{1}{\omega^2LC_{н}}$

From (3) and (5), respectively, for active-inductive and active-capacitive loads we get:

$$y_m^2=(\delta^2\beta_1^2+\gamma^2)Z_m+y_{cm}^2-2\gamma Z_my_{cm}, \qquad (5)$$

$$y_m^2=(\delta^2\beta_1^2+\gamma_c{}^2)Z_m^2+y_{cm}^2+2\gamma_cZ_my_{cm}, \qquad (6)$$

These dependencies are equations of second order curves representing ellipses. We bring these equations to canonical form by rotating the coordinate axes through some angle α. Old coordinates through new ones are determined by the following expressions: [9-14]

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$$Z_m = Z'_m \cos\alpha - \text{У}'_{cm} \sin\alpha$$

$$\text{У}_m = Z'_m \sin\alpha - \text{У}'_{cm} \cos\alpha$$

Here α is the angle of rotation of the axes.

Substituting these values in (5), we have:

$$AZ'^2_m + 2BZ'_m\text{У}'_{cm} + C\text{У}^2_{cm} = 0\ , \qquad (7)$$

Where

$$A = (\delta^2\beta_1^2 + \gamma^2)\cos^2\alpha + \sin^2\alpha - 2\gamma\sin\alpha\cos\alpha\ ,$$

$$B = (\cos^2\alpha + \sin^2\alpha) - (\alpha^2\beta_1^2 + \gamma - 1)\sin\alpha\cos\alpha = 0\ ,$$

$$C = (\delta^2\beta_1^2 + \gamma^2)\sin^2\alpha + \cos^2\alpha + 2\gamma\sin\alpha\cos\alpha = 0\ ,$$

The choice of the angle α is made in such a way that the coefficient B becomes zero. This will allow obtaining an expression for the angle of rotation γ $(\cos^2\alpha - \sin^2\alpha) - (\delta^2\beta_1^2 + \gamma - 1)\sin\alpha\cos\alpha = 0$,

From where

$$tg\, 2\alpha = -\frac{2\gamma}{\delta^2\beta_1^2 + \gamma - 1}$$

For active capacitive load

$$tg\, 2\alpha = \frac{2\gamma_c}{\delta^2\beta_1^2 + \gamma_c - 1}$$

Now we bring equation (7) to the form

$$AZ'^2_m + C\text{У}'^2_{cm} = \text{У}^2_m$$

Or

$$\frac{Z'^2_m}{\frac{\text{У}^2_m}{A}} + \frac{\text{У}'^2_{cm}}{\frac{\text{У}^2_m}{C}} = 1 \qquad (8)$$

Thus, the connection between Z_m and У_{cm} for a fixed value of the load is determined by the equation of the ellipse (8) and the known current-voltage characteristic of the current stabilizer circuit. The graphical method allows you to visually analyze the load mode of the current stabilizer and build the necessary characteristics of the device. [15-21] For the case of active load, the canonical form of the ellipse equation is as follows:

$$\frac{Z^2_m}{\frac{\text{У}^2_m}{\delta^2\beta_1^2}} + \frac{\text{У}^2_{cm}}{\text{У}^2_m} = 1 \qquad (9)$$

Using the known values of the semiaxes $\frac{\text{У}_m}{\delta\beta}$ and У_m plotted on the characteristics $Z_m = f(\text{У}_{cm})$ of the stabilizer of the ellipse. The intersection points define the corresponding values and Z_m and У_{cm}. Figures 2 and 3 show a graphical method for determining the quantities of interest for the case of active, active-inductive and active- capacitive characteristics. The constructed adjustment and external characteristics according to the graphical method [22-28]

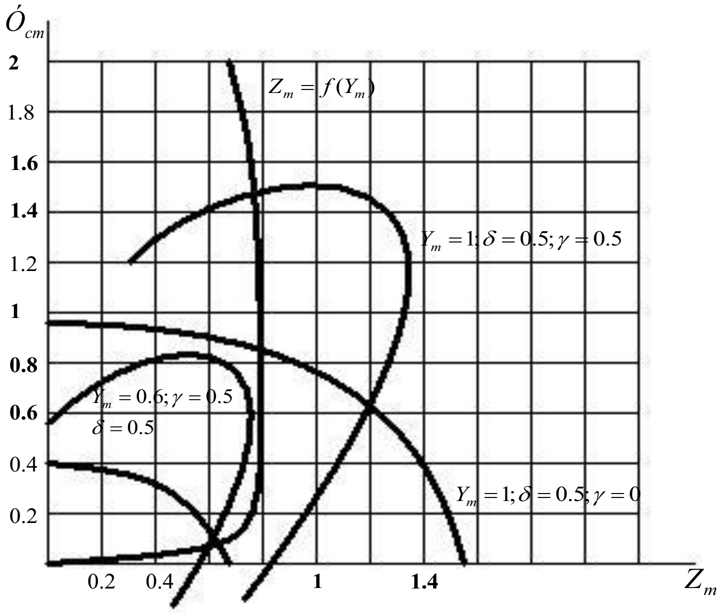
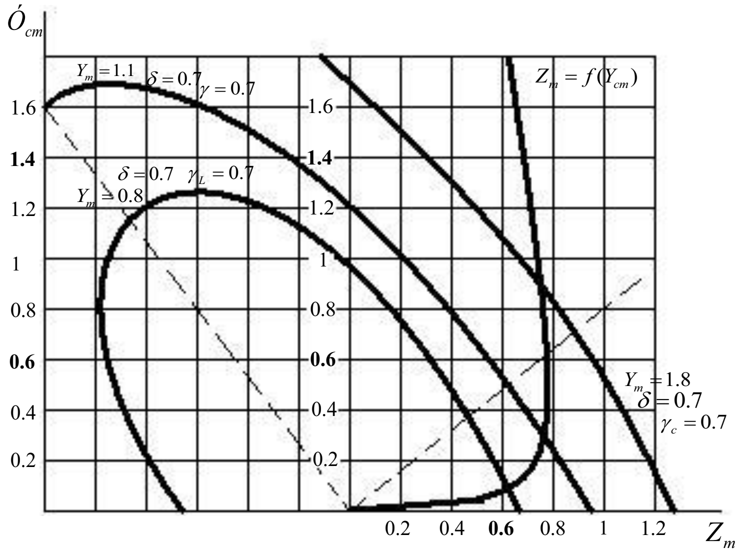


Figure: 2. Graphic method for determining Zm, Ucm



Conclusions

1. Based on the analysis of the three-element resonant circuit, the possibilities of stabilizing the load current are revealed.

2. The relationship between the load current and the voltage of a parallel connected capacitor for a fixed load value is determined by the ellipse equation and the current-voltage characteristic of the current stabilizer circuit, which allows you to visually analyze the load mode and build the necessary characteristics.

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