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Loading mode of a ferromagnetic current stabilizer

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Abstract. The article discusses the analysis of the steady-state mode of a ferrimagnetic current stabilizer with active-inductive and active-capacitive loads, for assessing energy and operational indicators. The constructed adjustment characteristics determine the zone of stabilizations, which depend on the parameters of the device.

1 Introduction

In order to clarify the influence of various load parameters on the operation of the ferrimagnetic current stabilizer and to assess the energy and performance indicators, we will consider the load mode of the device. Taking assumptions and neglecting losses in the magnetic amplifier, we will analyze the steady state for active, active-inductive and active-capacitive loads [1-7].

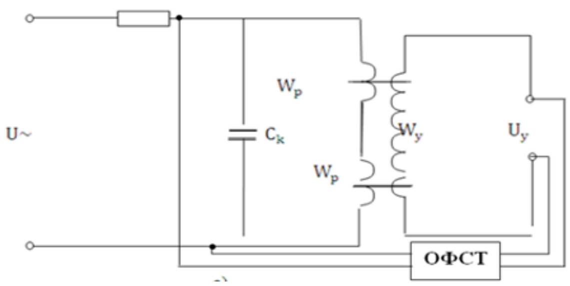

Fig. 1. Schematic diagram of a ferromagnetic current stabilizer

The equation of the electrical state of the circuit (Fig.1) for an active load is as follows:

$$u_c = R_H\left(i_c + i_{\text{фэ}}\right) + 2W_p \frac{d\Phi}{dt}, \tag{1}$$

where u_c– mains voltage, i_c – current flowing through the capacitor $C_к$

Let us assume that the magnetization curve of a ferromagnetic element is approximated by a power function, [8-14] then

$$i_p w_p + i_y w = k\phi^n \tag{2}$$

After introducing dimensionless quantities, taking into account (1) and (2), we have: $y = \delta\left(\frac{1}{m}\frac{d^2x}{d\tau^2} + i_{\text{фэ}}\right) + 2W_p\frac{d\Phi}{dt}$ (3)

Here

$$z + z_0 = x^n$$

$$z = \frac{i}{i_б};\; z = \frac{i_y}{i_б};\; i_б = \frac{k\Phi_б^n}{w};\; x = \frac{\Phi}{\Phi_б};$$

$$z_c = \frac{1}{m}\frac{d^2x}{d\tau^2}$$

$$\delta = \frac{R_H i_\delta}{2\omega W \Phi_\delta}; m = \frac{i_\delta}{2\omega^2 W C_k \Phi_\delta}; X = \frac{\Phi}{\Phi_\delta};$$

$$y = \frac{Uc}{U_\delta}; z = \frac{i}{i_\delta}; U_\delta = 2\omega W \Phi_\delta$$

Assuming that $y = Y_m\cos(\tau + \varphi)$

$$x = X_m sin\tau$$

$$z = Z_m sin\tau$$

From (3), after some trigonometric transformations, we obtain

$$y_m^2 = X_m^2 + \delta^2(Z_m - \frac{X_m}{m})^2 \tag{4}$$

$$tg\varphi = \frac{\delta(\frac{X_m}{m} - Z_m)}{X_m} \tag{5}$$

For further mathematical analysis, it is necessary to analytically express the characteristic $X_m=f(Z_m)$. In this case, it is convenient to take an approximating function of the following form:

$$X_m = aZ_m^4 \tag{6}$$

This dependence qualitatively describes the characteristic of simultaneous magnetization in the working section of the magnetic amplifier in the stabilization mode and gives rather simple results for analyzing the load mode of the device. The value of the coefficient depends on the magnitude of the bias current, and it can be determined by the method of selected points or by the method of least squares [15-22].

Substituting (6) into (4), we have:

$$Y_m^2 = a^2Z_m^8 + \delta^2\left(Z_m - \frac{1}{m}aZ_m^4\right)^2 \tag{7}$$

Based on this expression, we can construct the control characteristic of the current stabilizer for various load resistances. The latter is characterized by the value of δ, the possible maximum value of which is determined on the basis of the I – V characteristic of the circuit of the ferromagnetic current stabilizer.

From the characteristics of the circuit of the ferromagnetic current stabilizer (Fig. 2), it can be seen that stabilization begins with X_m=0,4 and continues until X_m=1,2. Thus, if we assume Y_m=1,2, then the maximum voltage drop across the load should be determined by the following formula:

$$Y_{nm} = \sqrt{Y_m^2 + X_m^2}$$

Knowing the value of the stabilization current, we determine $\delta = \frac{Y_{nm}}{Z_m} = 0{,}44; \qquad Z_m = 2{,}5$

This means that in the stabilization mode, a change is allowed δ in the range from zero to 0.44. In this case, the input voltage should be =1.2. Fig.2 shows the control characteristics of the device for various values of active resistance, built on the basis of (7). For this case, the ratio of the installed power of the elements of the ferromagnetic current stabilizer to the load power is determined as follows:

$$q = \frac{\Sigma|Q|}{P_н} = \frac{|Q_{my}| + |Q_k|}{P_н} \tag{8}$$

There Q_{my} - maximum power of the magnetic amplifier;

Q_k - power of the compensating capacitor.

Considering that

$$Q_{my} = Z_{my} * Y_m; \qquad Z_{my} = 3{,}75; \qquad Y_m = 1{,}2; \qquad Q_k = Z_{mk} * Y_{mk}; \qquad Z_m = 1{,}2$$

from (8) we obtain that q≈2.

Thus, the installed power of the elements of the current stabilizer is more than 2 times higher than the load power. This indicator is more than two times less than that of the considered FTS [23-32].

For the case of active-inductive load based on the following circuit equation

$$u = R_н\left(i_c + i_{\phi э}\right) + L\frac{d}{dt}\left(i_c + i_{\phi э}\right) + 2W\frac{d\phi}{dt} \tag{9}$$

after simple transformations and introduction of normalized values, we obtain

$$y = \delta(Z_c + Z_{\phi э}) + \gamma_H\frac{d\phi}{d\tau}(Z_c + Z_{\phi э}) + \frac{d\phi}{d\tau} \tag{10}$$

Here

$$\delta = \frac{L_H i_\delta}{2W\phi_\delta} \quad Z_c = \frac{i_c}{i_\delta} \quad Z_{\phi э} = \frac{i_{\phi э}}{i_\delta}$$

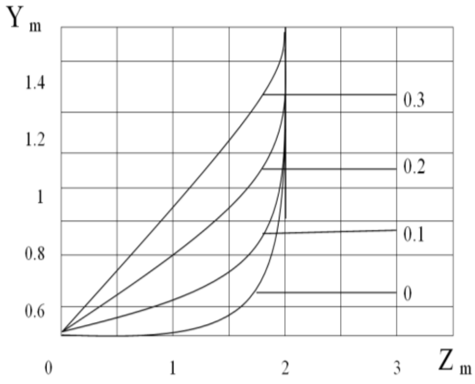

Fig. 2. Control characteristics for resistive load

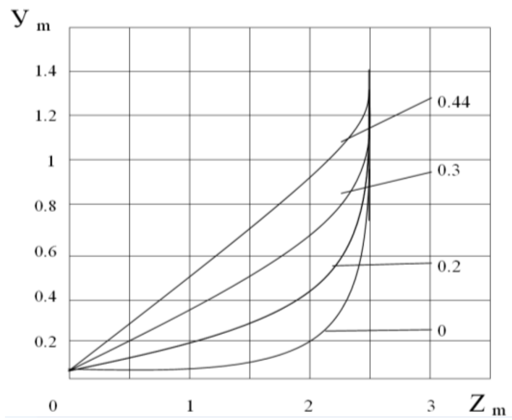

Fig. 3. Control characteristics for active-inductive load

Considering that:

$$Z_c = \frac{1}{m}\frac{d^2x^2}{d\tau^2}$$

$$y = Y_m\cos(\tau + \varphi) \tag{11}$$

$$x = X_m\sin\tau \qquad z_{\phi э} = Z_{m\phi э}\sin\tau$$

If we take the approximating function of the curve of simultaneous magnetization of a ferromagnetic element in the form (6), then after some transformations, we get:

$$Y_m^2 = \delta^2(Z_{m\phi э} - \frac{\alpha Z}{m})^2 + \left[\gamma_H(Z_{m\phi э} - \frac{\alpha Z_{m\phi э}^4}{m}) + \alpha Z_{m\phi э}^4\right]^2 \tag{12}$$

Based on the last dependency, given that

$$Z_{mcT} = Z_{m\phi э} - \frac{\alpha Z^4_{m\phi э}}{в}$$

we can build the regulating characteristics of the current stabilizer for different values (Fig. 3) of active-inductive load. For an active - capacitive load, the circuit equation is as follows;

$$\frac{du}{dt} = R_H \frac{d\phi}{dt}(i_c + i_{\phi э}) + \frac{i_c + i_{\phi э}}{C_k} + W\frac{d^2\phi}{dt^2}$$

After a series of transformations, we have

$$Y_m^2 = \delta^2 (Z_{m\phi э} - \frac{\alpha Z^4_{m\phi э}}{в})^2 + \left[\alpha Z^4_{m\phi э} - \gamma (Z_{m\phi э} - \frac{\alpha Z^4_{m\phi э}}{m}\right]^2 \quad (13)$$

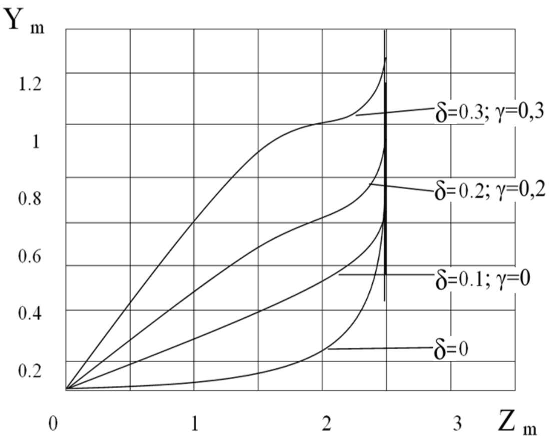

Fig. 4. Control characteristics for active-capacitive load

Here

$$\gamma = \frac{i_\delta}{2\omega^3 W C_H \Phi_\delta}$$

Thus, expressions (12) and (13) differ from each other only in signs in front of the coefficients $\gamma_н$ and γ, which are proportional to the inductive and capacitive resistance of the loads. In fig. 4. shows the nature of the change in the control characteristics for various values of complex loads. Whence, the active-capacitive load is favorable for the current stabilization mode, since the voltage stabilization range is wider in comparison with the inductive nature of the load, when the same values are taken δ and γ [33-41].

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