Stability in a parallel resonant circuit with active load

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Abstract: This article examines the stability of excited oscillations in resonant circuits in order to determine the possibility of their application to control thyristors in the function of changing the input voltage value. In resonant circuits connected to a voltage source with a low internal resistance, the occurrence of stable oscillations depends significantly on the value of the parameters of the circuit under consideration.
Key words: stationary oscillations, phase of oscillations, stability, state of quilibrium.

Introduction

In resonant circuits connected to a voltage source with a low internal resistance, for a certain combination of parameters, the excitation of oscillations at the fundamental frequency is observed, the initial phase of which has a shift with respect to the phase of the applied voltage. Moreover, the phase of the excited oscillations depends on the magnitude of the applied emf. [1-6].

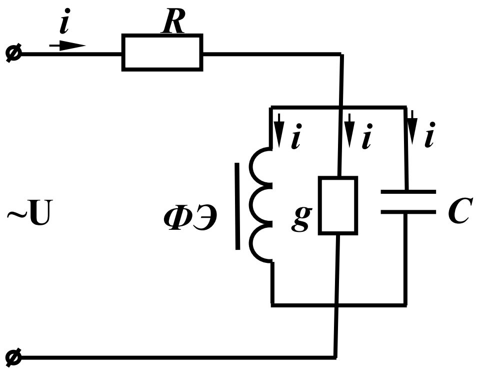

Figure: 1. Equivalent circuit of a parallel resonant circuit with active resistance connected in series to it.

This article discusses the stability of stationary oscillations arising on an unbranched section of the circuit (Fig. 1) in order to determine the possibility of them. thyristors as a function of voltage [7-10].

The investigated circuit is described by the following differential equation:

$$u = w\frac{d\phi}{dt} + Ri \qquad (1)$$

Where

$i = i_C + i_g + i_{ФЭ}$

Here $i_C = wC\frac{d^2\phi}{dt^2}$; $i_g = wg\frac{d\phi}{dt}$; $i_{ФЭ} = \frac{K}{w}\phi^7$

Substituting the corresponding values of the currents into equation (1), we obtain

$$u = w\frac{d\phi}{dt} + wCR\frac{d^2\phi}{dt^2} + wgR\frac{d\phi}{dt} + \frac{KR}{w}\phi^7 \qquad (2)$$

Introducing the basic and dimensionless quantities corresponding to equation (2), as well as dimensionless coefficients:

$$y = \frac{u}{U_б}; \quad x = \frac{\phi}{Ф_б}; \quad Ф_б = \sqrt[6]{\frac{64\omega^2 w^2 C}{35K}};$$

$$U_б = \omega w Ф_б; \quad \tau = \omega t \quad \delta = \omega CR; \quad \xi = gR.$$

We rewrite equation (3)

$$y = \delta\frac{d^2x}{d\tau^2} + (1+\xi)\frac{dx}{s\tau} + \delta\frac{64}{35}x^7 \qquad (3)$$

Solving this differential equation, we obtain:

$$-y_m Sin\psi = 2\delta\frac{dX_m}{d\tau} + (1+\xi)X_m \qquad (4)$$

$$y_m Cos\psi = 2\delta\delta_m\frac{d\psi}{d\tau} + \delta X_m(X_m^6 - 1)X_m . \qquad (5)$$

Stationary solution

$$-y_m Sin\psi = (1+\xi)X_m \qquad (6)$$

$$y_m Cos\psi = \delta X_m(X_m^6 - 1)X_m \qquad (7)$$

Solving together equations (4) and (5) we obtain the amplitude value of the input voltage in relative units.

$$y_m = X_m\sqrt{(1+\xi)^2 + \delta^2(X_m^6 - 1)}. \qquad (8)$$

With a sinusoidal mains voltage, both natural and forced oscillations occur in the ferroresonant circuit. at certain ratios of parameters in the current-voltage characteristic of the circuit, it can cause the appearance of a region of ambiguity of solutions. Therefore, we will consider the issues of stability of the obtained solutions for the stationary state of the ferroresonant circuit [11-16].

Let us consider the question of the stability of the obtained solution, based on the Lyapunov theory. For the circuit under consideration, we rewrite the differential equation (4) and (5) as follows, taking the generally accepted notation

$$2\frac{dX_m}{d\tau} = -\frac{y_m}{\delta} Sin\psi - \frac{1+\xi}{\delta} X_m = F = A(X_m;\psi)$$
$$2\frac{d\psi}{d\tau} = -\frac{y_m}{\delta X_m} Cos\psi + (X_m^6 - 1) = B(X_m;\psi) \quad (9)$$

The equilibrium state is determined by the roots of the system of equations $A(X_m;\psi)$ and $B(X_m;\psi)$

Consider some equilibrium state x_k and ψ_k.

According to the accepted methodology.

$$x = x_k + \varepsilon; \qquad \psi = \psi_k + \eta$$

In new variables, equation (9) has the form:

$$\frac{d\varepsilon}{d\tau} = A(x_k + \varepsilon;\ \psi_k + \eta); \qquad \frac{d\eta}{d\tau} = B(x_k + \varepsilon;\ \psi_k + \eta)$$

The variables ε and η represent the displacement from the equilibrium state. We expand the functions A and B into a Taylor series in ε and η near the point x_k and ψ_k, limiting ourselves to the expansion terms

$$\frac{d\varepsilon}{d\tau} = A(x_k;\psi_k) + \frac{dA(x_k;\psi_k)}{d\tau} + \frac{dB(x_k;\psi_k)}{d\psi} + \dots.$$
$$\frac{d\eta}{d\tau} = B(x_k;\psi_k) + \frac{dA(x_k;\psi_k)}{d\tau} + \frac{dB(x_k;\psi_k)}{d\psi} + \dots.$$

that is, a linear equation with constant coefficients. According to Lyapunov's theory, the system of the first approximation is not stable if the real parts of both roots of the characteristic equation are equal to zero or if one root is equal to zero and the second is negative, the coefficients of the characteristic equation of the system of the first approximation are $\lambda^2 + p\lambda + q = 0$ determined by the expressions

$$p = -\left| \frac{dA(x_k;\psi_k)}{dx} + \frac{dB(x_k;\psi_k)}{d\psi} \right|$$
$$q = \begin{vmatrix} \frac{dA(x_k;\psi_k)}{dx} & \frac{dA(x_k;\psi_k)}{d\psi} \\ \frac{dB(x_k;\psi_k)}{dx} & \frac{dB(x_k;\psi_k)}{d\psi} \end{vmatrix} \quad (10)$$

The condition for the stability of the system according to the Hurwitz criterion is

$$p > 0, \ q > 0$$

To determine the question of stability of the considered ferroresonant circuit, we use the given theory of Lyapunov [17-19].

From system (9) we define

$$\frac{dA}{dx} = -\frac{1+\xi}{\delta} \qquad \frac{dA}{d\psi} = -\frac{y_m}{\delta} Cos\psi$$
$$\frac{dB}{dx} = -\frac{y_m}{\delta X_m} Cos\psi + 6X_m^5 \qquad \frac{dB}{d\psi} = \frac{y_m}{\delta X_m} Sin\psi \quad (11)$$

From (6) and (7) we define

$$Sin\psi = -(1+\xi)\frac{X_m}{y_m}$$
$$Cos\psi = \delta(X_m^6 - 1)\frac{X_m}{y_m}$$

Let us substitute in (11) the values of ***Sinψ*** and ***Cosψ***. Then we will have

$$\frac{dA}{dx} = -\frac{1+\xi}{\delta} \qquad \frac{dA}{d\psi} = (1 - X_m^6)X_m$$
$$\frac{dB}{dx} = -\frac{1 - X_m^6}{X_m} + 6X_m^6 \qquad \frac{dB}{d\psi} = -\frac{1+\xi}{\delta} \quad (12)$$

From (12) by expressions (10) we obtain the roots of the characteristic equation

$$p = \frac{2(1+\xi)}{\delta}; \quad (13)$$

$$q = \left(\frac{1+\xi}{\delta}\right)^2 - (1 - X_m^6)^2 - 6X_m^6(1 - X_m^6) \quad (14)$$

The first condition $p > 0$ does not limit the stability of the solution, since it is $(1+\xi)/\delta$ always greater than zero. Therefore, to determine the stability of the solution, it is sufficient to calculate the value of q [20-22].

Conclusions

Have shown that the solution corresponding to a steady state depends significantly on the values of the parameters ***C, g*** and ***R***.

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