Energy-saving electric drive.

Abstract: There are known DC and AC electric drives with excitation control, containing negative feedback circuits for speed and the derivative of the flow. In such drives, the efficiency always decreases proportionally to the number of links included in them, as the number of elements included in them increases. That is, if the power supplied to the drive motor is $P_{el} = I \times U$, then the power on the drive motor shaft will be equal to:

$P_{DM} = P_{el} \times K_{DM}$, where

K_{DM} - is the efficiency of the drive motor.

The power will be removed from the generator:

$P_{DM} = P_{el} \times K_{DM} \times K_G$, where

K_G is the efficiency of the generator.

Further, the consumed power will also decrease as the number of links included in the chain with other consumers increases.

The device described below relates to the field of electrical engineering, namely to electric drives with speed feedback. The drive uses a parallel oscillatory circuit in which the current resonance is achieved. This parallel oscillatory circuit has a built-in brushless anchor of a synchronous AC motor DCm, which is powered by a brushless anchor of an AC generator G made according to the synchronous generator scheme. The anchor of the generator G and the DCm motor are on the same shaft, forming a single system, which is driven by the drive motor DM. At current resonance in the parallel oscillatory circuit, the active current in the branched section of the circuit, where the anchor of the DCm motor is located, can be many times greater than the active current in the unbranched section of the circuit, where the anchor of the generator G is located. Thus, the technical result of using this drive is saving electricity supplying the drive motor DM of the device.

Key words: consumed power, output power, electric drive with parallel resonant circuit, generator-motor system (G - DC m) on one shaft.

There are known DC and AC electric drives with excitation control, containing negative feedback circuits for speed and the flow derivative. In such drives, the efficiency always decreases proportionally to the number of links included in them, as the number of elements included in them increases. That is, if the power supplied to the drive motor is Pel. = I U , then the power on the drive motor shaft will be equal to:

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Then the consumed power will also decrease as the number of links included in the chain with other consumers increases.

The device described below pertains to the field of electrical engineering, namely to electric drives with speed feedback. The technical result of its application is the saving of electricity supplying the drive motor of the device. The electric drive contains: a tachogenerator TG with a magnetic amplifier MA and negative feedback circuits for speed and flux derivative; a drive motor DM, which is powered by a power source PS; an energy-saving device G-DCm, which contains: a synchronous alternating current generator G, the armature winding of which does not have a collector (because it does not have a voltage and current output to the external circuit) and is directly connected to a parallel oscillatory circuit in which the motor armature DCm is built in. The motor armature DCm operating in the synchronous motor mode also does not have a collector and is powered directly from the generator armature G. The generator armature G and the motor armature DCm are located on the same shaft. At the same rotation speed of the shaft on which they are located, the voltage on the armature operating in the generator mode should be 1.5 - 2.5 times greater than the voltage on the armature operating in the motor mode. The mechanical and electrical circuit of the drive is shown in Figure 1.

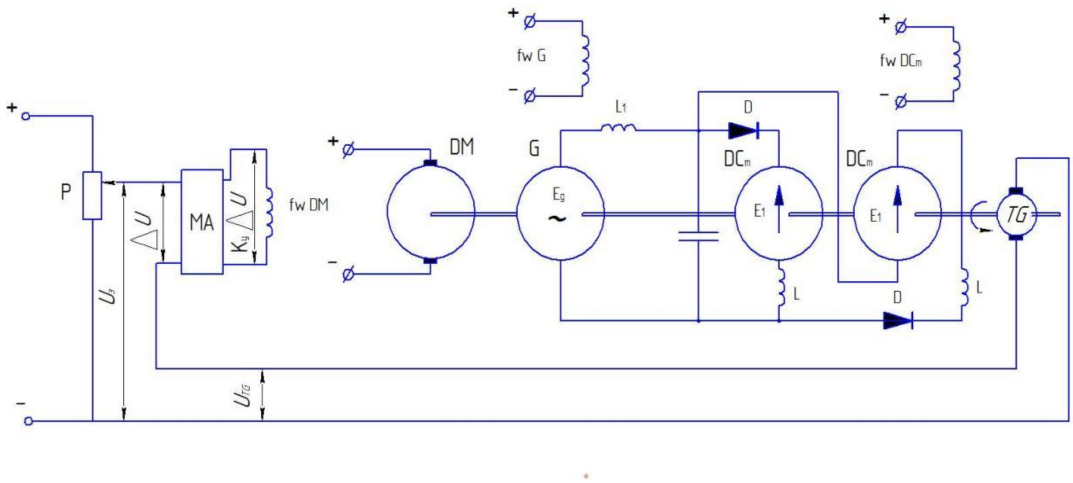

Fig. 1. Schematic diagram of an electric drive with a parallel resonant circuit.

The direct current tachogenerator measures the actual rotation frequency of the system located on one shaft. At the input resistance of the amplifier MA, the setting voltage U_3 , which is a function of the set rotation frequency, is compared with the voltage of the tachogenerator U_{TG} , proportional to the rotation frequency of the system located on one shaft. When the rotation frequency of the system located on one shaft deviates from the set speed, the voltage difference $\Delta U = U_3 - U_{TG}$, supplied to the amplifier changes. The voltage $K_U \times \Delta U$ from the amplifier output goes to the control winding of the magnetic amplifier, is amplified by k times and is fed to the excitation winding of the DM motor and the excitation winding of the armature operating in the DCm motor mode. The rotation frequency of the DM motor and the entire system located on a common shaft will change so that the deviation of its value from the set value will decrease.

The counter-EMF of the armature operating in the synchronous motor mode is directed opposite to the EMF of the armature operating in the synchronous generator mode. Diodes D prevent the current from flowing in the direction of the counter-EMF of the armature winding operating in the motor mode. It is evident from the figure that this is a circuit with a parallel connection in the branched part of the capacitor and inductance circuit, in which the circuit elements are selected in such a way that parallel resonance is realized during the operation of the circuit.

The system operates as follows. The drive motor accelerates the generator anchor G - motor anchor DCm system located on the same shaft to the speed at which they start working. As was said above, the ratings of the capacitor C, inductance L, and resistance R_2 are selected in such a way that at the operating frequency of the generator anchor G, a resonance of currents occurs in the circuit with an amplitude of current oscillations in the branched part of the circuit many times exceeding the amplitude of oscillations in the unbranched part of the circuit. If the electric circuit contains reactive elements connected in series and in parallel, partial resonances may occur in the circuit when the input voltage and current are in phase. If the inductive resistance of the unbranched part of the circuit is compensated by the capacitive resistance of the parallel circuit, a resonance of voltages in the unbranched part of the circuit will be observed. This will negatively affect the operation of the drive. Therefore, the inductive resistance of the generator armature winding G of the unbranched part of the circuit must be compensated by introducing capacitive resistance into the unbranched part of the circuit, and the reactive part in the unbranched section of the circuit must be equal to zero. The generator armature must have only active resistance.

In Fig. 1, the inductive resistance of the generator anchor G and the capacitive resistance compensating it are not shown conditionally. Let us designate the active resistance of the generator anchor as R1 and consider the circuit with the definition of specific parameters of the circuit.

Let's use Figure 2 for this.

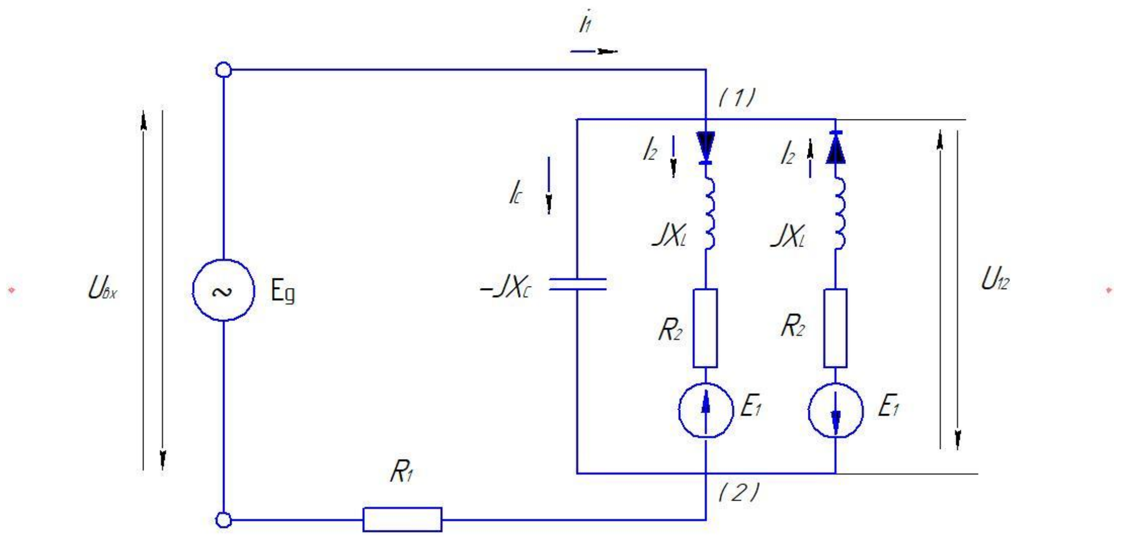

Fig. 2 Complex circuit with parallel resonant circuit

Let's consider an example of an electrical circuit of a G - DCm system on one shaft with a parallel resonant circuit.
For a complex circuit, using the available data, we will determine the inductive resistance of the coil X_L, the resistance of the resistor R_2, at which the resonance phenomenon will be observed in the circuit. We will determine the quality factor of the oscillatory circuit, complex currents in resonance mode and the power given off by the generator and consumed by the engine.

Let U_{BX} = 100 V; i_1 = 10 A; R_1 = 1 Ohm; $Xc = \frac{1}{2\pi f C}$ = 0,1 Ohm

E_1 = 50 V, f_{BX} = 50 Hz

Solution. The circuit in Fig. 1 operates with a harmonic input effect. It is important to note that the problem statement specifies the effective values of the input voltage and current. Resonance in the circuit will occur when the input current and input voltage are in phase. This will happen when the capacitive admittance of the capacitor is compensated by the inductive admittance of the R_2 - L branch parallel to the capacitor (current resonance). In this case, resistor R_1 does not affect the phase characteristics of the parallel circuit, therefore, the current resonance condition in the circuit can be written as $I_m[Z_I \text{ cont}] = 0$, where $Y_{BX \text{ cont}}$ - is the complex admittance of the R_2 - L - C resonant circuit:

$$Y_{BX \text{ cont}} = \frac{1}{-jX_C} + \frac{1}{R_2 + jX_C} = \frac{J}{X_C} + \frac{R_2}{R_2^2 + X_L^2} - \frac{X_L}{R_2^2 + X_L^2}\, \mathrm{j}$$

Let's equate the imaginary part of the circuit's conductivity to zero:

$$\frac{1}{X_c} - \frac{X_L}{R_2^2 + X_L^2} = \frac{1}{0{,}1} - \frac{X_L}{R_2^2 + X_L^2} = 0$$

In this equation there are two unknown resistances: R_2 and X_L. Let's make another equation using Ohm's law:

$$\frac{U_{BX}}{I_{BX}} = Z_{BX} = R_1 + Z_{BX.\,cont} = R_1 + \frac{R_2^2 + X_L^2}{R_2}$$

The equation is written for complex current and voltage, and only their effective values are specified. That is, the lengths of the vectors on the complex plane are specified, there is no information about phase shifts, and the reference signal relative to which the phases are determined is not specified. In this case, any voltage or current in the circuit can be taken as the reference signal. The calculation will be simplest if the input current is taken as the reference signal ($\alpha = 0°$). Then the complex value of the current can be calculated:

$$I_{BX} = i_1 \times \cos 0° + i_1 \times \sin 0° = 10 \text{ A}$$

In resonance mode, the input voltage and current are in phase. Then the complex value of the input voltage is:

$$U_{BX} = \text{U} \times \cos 0° + \text{U} \times \sin 0° = 100 \text{ V}$$

Now the system of equations for calculating R_2 and X_L takes the form:

$$\frac{1}{0{,}1} - \frac{X_L}{R_2^2 + X_L^2} = 0$$

$$\frac{100}{10} = 1 + \frac{R_2^2 + X_L^2}{R_2}$$

Solving the system, we obtain the values $R_2 \approx 0{,}00111$, $X_L \approx 0{,}1$

$$X_L = 2 \times \pi \times f \times \text{L}, \quad \rightarrow \quad \text{L} = \frac{X_L}{2 \times \pi \times f} = \frac{0{,}1}{6{,}28 \times 50} = 0{,}0003183 \text{ H}$$

$$X_C = \frac{1}{2\pi f C} = 0{,}1 \quad \rightarrow \quad \text{C} = \frac{1}{2 \times \pi \times f \times X_C} = \frac{1}{6{,}28 \times 50 \times 0{,}1} = 0{,}03183 \text{ F}$$

$$g_C = \frac{1}{X_C} = 10$$

Let us write the input conductivity of the resonant circuit in the form

$$Y_{BX.\,cont} = g_{Reg} = \frac{J}{X_C} + \frac{R_2}{R_2^2 + X_L^2} - \frac{X_L}{R_2^2 + X_L^2}\,j = \frac{j}{0{,}1} +$$

$$\frac{0{,}00111}{0{,}01} - \frac{0{,}1}{0{,}01}\,j = 10J + 0{,}111 - 10J = 0{,}111$$

Let's calculate the quality factor of the resonant circuit:

$$Q = \frac{g_C}{g_{Reg}} = \frac{10}{0{,}111} = 90{,}1\ ,\quad \text{where}$$

$g_C = \frac{1}{X_C}$ — module of capacitive conductivity of the resonant circuit;
g_{Reg} — module of the input conductivity of the circuit.

The quality factor of a resonant circuit shows how many times the current i_2 in the branched part of the circuit is greater than the current i_1 in the unbranched part of the circuit.

To determine the complex currents i_2 and i_1, we calculate the voltage U_{12} (see Fig. 2):

$$U_{12} = \frac{i_1}{Y_{BX.\ cont}} - E_1 = \frac{10}{0{,}111} - 50 = 90{,}1 - 50 = 40{,}1\ V$$

We will determine the currents according to Ohm's law:

$$i_2 = \frac{U_{12}}{R_2 + JX_L} = \frac{40{,}1}{0{,}00111 + 0{,}1\,J} = 396{,}6 - 40{,}1J$$

$$i_C = \frac{U_{12}}{-jX_C} = \frac{40{,}1}{-0{,}1J} = 40{,}1J$$

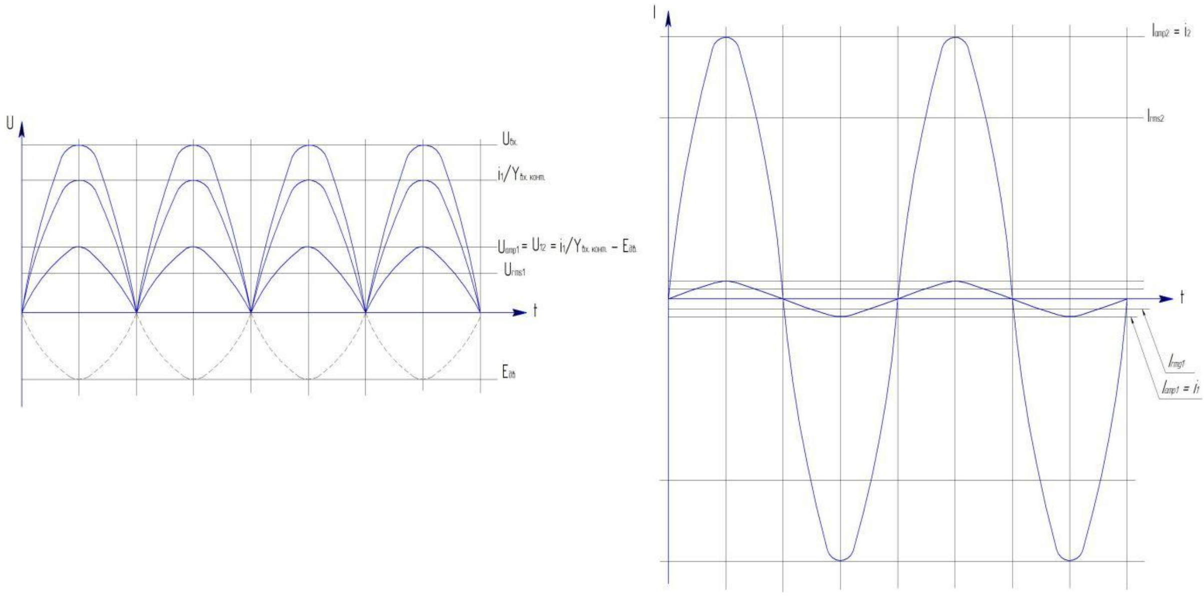

Fig. 3 Voltages and currents in the branches of an electric drive with a parallel resonant circuit.

The power supplied by the alternating current generator to the circuit with a parallel resonant circuit with a voltage of U_{BX} =100 V and a current of i_1 is determined by the formula:

$$P_{avg1} = U_{rms1} \times I_{rms1}\,,$$ where

P_{avg1} – the arithmetic mean value of the armature power operating in generator mode G,

U_{rms1} – the root mean square value of the armature voltage operating in the generator mode G,

I_{rms1} – the root mean square value of the armature current operating in the oscillator mode G.

The root mean square value of the armature voltage operating in generator mode is:

$$U_{rms1} = \frac{U_{amp1}}{\sqrt{2}} = \frac{100}{1,4142} = 70,7 \text{ V},$$ where

U_{amp1} - the amplitude value of the armature voltage operating in generator mode.

The root mean square value of the armature current operating in generator mode is:

$$I_{rms1} = \frac{I_{amp1}}{\sqrt{2}} = \frac{10}{1,4142} = 7,07 \text{ A},$$ where

$I_{amp1} = i_1$ - amplitude value of the armature current, operating in generator mode.

The power supplied by the alternating current generator to the circuit is equal to:

$P_{avg1}= U_{rms1} \times I_{rms1}$ = 70,7 × 7,07 = 500 W

The power received by the anchor operating in the DCm motor mode with a parallel resonant circuit, with a total voltage on the circuit U_{12}= 40,1 V and a current of i_2 in the circuit is determined by the formula:

$P_{avg2} = U_{rms2} \times I_{rms2}$, where

U_{rms2} - the total root-mean-square voltage between points 1 and 2 of the parallel circuit in which the anchor is located, operating in DCm motor mode.

I_{rms2} - the root mean square value of the current passing through the armature operating in DCm motor mode.

The root mean square value of voltage between points 1 and 2 is:

$U_{rms2} = \frac{U_{amp2}}{\sqrt{2}} = \frac{40,1}{1,4142} =$ 28,4 В , где

$U_{amp2} = U_{12}$ –the total amplitude voltage between points 1 and 2 of the parallel circuit in which the anchor is located, operating in the DCm motor mode.

$I_{rms2} = \frac{I_{amp2}}{\sqrt{2}} = \frac{396,6}{1,4142} =$ 280,44 A , где

$I_{amp2}= i_2$ – the peak value of the current passing through the armature operating in DCm motor mode.

The power of the anchor operating in the motor mode will be equal to:

$P_{avg2}= U_{rms2} \times I_{rms2}$ = 28,4 × 280,44 = 7964,5 Вт

Thus, according to the obtained approximate calculation, in the system of generator G - DCm motor on one shaft with a parallel circuit, it is possible to obtain additional power to the power consumed by the system.

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