THE AC SINGLE-PHASE ELECTROMAGNETS' OPERATING SUPPLIED WITH DOUBLE RECTIFIED VOLTAGE

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Abstract **– The AC single-phase electromagnets' operating and usage is decreased because of the vibration problem in the case of movable armature. In general this problem is avoided by using of shortcircuit turns placed on the magnetic core poles. The operating effectiveness of these shortcircuit turns is evaluated by the pulses of the resultant attraction force, with less possible sub-unit values. A nowadays solution to eliminate the vibration of the movable armature at AC single-phase electromagnets, means to supply their coil with double rectified voltage with the RMS value of the AC voltage applied to rectifier bridge in order to magnetic core operates at the same values of the magnetic flux. Computing in this case the pulses of the attraction force, it observes less values respect to optimal situation of shortcircuit turns operating that confirms the possibility to eliminate these screen turns with doubtless technological and operating advantages.**

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1. INTRODUCTION

The analysis of the screen turns operating used to eliminate the vibration of the movable armature in the case of the AC single-phase electromagnets, [1, 3], refers to the case when the movable armature is turned on, and it allows the evaluation of the resultant attraction force pulses, p:

$$p = \frac{\sqrt{1-2(m-3)x+(m+1)(m+9)x^2}}{1+(m+3)x} \qquad (1)$$

The values are influenced by the ratio m, (screened area/not-screened area respect to magnetic core poles), and the $\sin^2\varphi_{sc} = x$, where φ_{sc}, means the own phase shift of screen turns because of the electric resistance, R_{sc} and its inductance, L_{sc}.

It may define the minimum attraction force for these kind of electromagnets:

$$F_{min} = F_{med} - F_{\sim} = F_{med}(1-p) \qquad (2)$$

where F_{med}, means the average attraction force and $F_{\sim}$, is the oscillatory attraction force.

The condition to eliminate the vibrations is:

$$F_{min} \geq F_{Rmax}, \qquad (3)$$

where F_{Rmax}, means the maximum resistance force which acts on the movable armature of the electromagnets.

It can notice that in the case of the U-I single-phase electromagnets with shortcircuit turns, the optimal operating of these ones is done for, [2]:

$$m = 4,\ x = 0.0625 \qquad (4)$$

hence, the optimal value of the pulse is p = 0.7853.

2. AC SINGLE-PHASE ELECTROMAGNETS WITH COIL SUPPLIED BY DOUBLE RECTIFIED VOLTAGE

To supply the coil of the AC single-phase electromagnets with a double rectified voltage means a solution to eliminate the vibration of the movable armature, Fig.1.

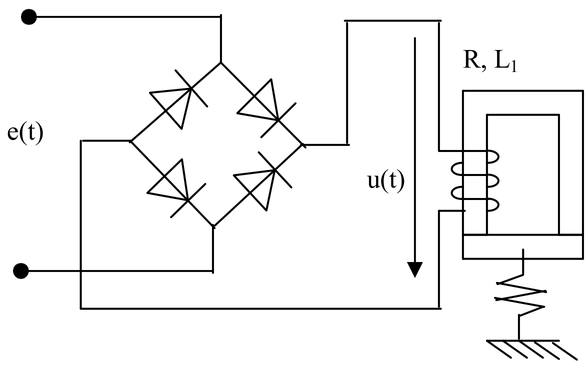

Figure 1: Electric circuit to supply with double rectified voltage the electromagnet coil.

If the alternative supply voltage is given by the expression:

$$e(t) = \sqrt{2}E\sin\omega t \qquad (5)$$

then the Fourier series of the voltage applied to the coil, u(t), it can be written as follows:

$$u(t) = \frac{2\sqrt{2}E}{\pi}[1 + \frac{2}{3}\sin(2\omega t + \gamma_2) + \frac{2}{15}\sin(4\omega t + \gamma_4) + \\ ... + \frac{2}{(2k-1)(2k+1)}\sin(2k\omega t + \gamma_{2k}) + ...] \tag{6}$$

which shows the presence of the even harmonics.

Considering only the first two terms of the Fourier series of the voltage u(t), the current which flows through the electromagnet turns in the case of the steady-state conditions, will be:

$$i(t) \cong \frac{2\sqrt{2}E}{\pi}\frac{1}{R} + \\ + \frac{2\sqrt{2}E}{\pi}\frac{2}{3}\frac{1}{\sqrt{R^2 + 4\omega^2 L_1^2}}\sin(2\omega t + \gamma_2 - \varphi_2) \tag{7}$$

where, $\varphi_2 = arctg\frac{2\omega L_1}{R}$.

The total magnetic flux inside the electromagnet core, defined by the inductance L_1 of its coil, result:

$$\psi(t) = i(t)L_1 = \frac{2\sqrt{2}E}{\pi\omega}(\frac{\omega L_1}{R}) + \\ + \frac{2\sqrt{2}E}{\pi\omega}\frac{2}{3}\frac{\omega L_1}{\sqrt{R^2 + 4\omega^2 L_1^2}}\sin(2\omega t + \gamma_2 - \varphi_2) \tag{8}$$

which contains a continuous component Ψ_0, and a variable component with 2ω pulses, by magnitude Ψ_2:

$$\psi_0 = \frac{2\sqrt{2}E}{\pi\omega}\frac{\omega L_1}{R}, \ \psi_2 = \frac{4\sqrt{2}E}{3\pi\omega}\frac{\omega L_1}{\sqrt{R^2 + 4\omega^2 L_1^2}} \tag{9}$$

The expressions for Ψ_0 and Ψ_2, from the above equations, can be written like an equivalent form:

$$\psi_0 = \frac{2\sqrt{2}E}{\pi\omega}\varepsilon, \ \psi_2 = \frac{4\sqrt{2}E}{3\pi\omega}\frac{\varepsilon}{\sqrt{1 + 4\varepsilon^2}}, \ \varepsilon = \frac{\omega L_1}{R} > 1 \tag{10}$$

where the ratio ε, characterizes the construction of the electromagnet coil.

According to these components of the total magnetic flux, the attraction force which acts upon movable armature of the electromagnet, underlines an average component, F'_{med}:

$$F'_{med} = k(\psi_0^2 + \frac{1}{2}\psi_2^2) \tag{11}$$

and an oscillatory component:

$$F'_{\approx} = \frac{1}{2}k\psi_2^2 \tag{12}$$

The pulses of the resultant attraction force for the AC single-phase electromagnets supplied with double rectified voltage, is:

$$p' = \frac{F'_{\approx}}{F'_{med}} = \frac{\frac{1}{2}\psi_2^2}{\psi_0^2 + \frac{1}{2}\psi_2^2} < 1 \tag{13}$$

Taking into account the (10), after computations, the pulse p', has the expression:

$$p' = \frac{2}{2 + 9(1 + 4\omega^2)} < 1 \tag{14}$$

with sub-unit values which confirms the possibility to eliminate the vibrations of the movable armature for these kind of electromagnets without the intervention of the screen turns.

3. COMPARISON BETWEEN AC SINGLE-PHASE ELECTROMAGNETS AND THE ELECTROMAGNETS SUPPLIED WITH DOUBLE RECTIFIED VOLTAGE FROM THE POINT OF VIEW OF VIBRATION ELIMINATION OF THE MOVABLE ARMATURE

Considering an AC single-phase electromagnet type U-I with screen turns supplied from an AC power supply with the RMS value by E, the RMS value of the total magnetic flux will be:

$$\psi = \frac{E}{\omega\sqrt{R^2 + \omega^2 L_1^2}}L_1 = \frac{E}{\omega}\frac{1}{\sqrt{1 + \varepsilon^2}}, \ \varepsilon = \frac{\omega L_1}{R} \tag{15}$$

where R and L_1 are the resistance, respectively the inductance of the electromagnet coil with movable armature turned on and ω means the power supply pulse.

For the same electromagnet with the coil supplied with double rectified voltage, see (10), the RMS value of the total magnetic flux will be:

$$\psi^* = \sqrt{\psi_0^2 + \frac{1}{2}\psi_2^2} \tag{16}$$

the final expression being:

$$\psi^* = \frac{2\sqrt{2}E^*}{\pi\omega}\sqrt{\varepsilon^2 + \frac{2}{9(1+4\varepsilon^2)}} \tag{17}$$

where E^* means the RMS value of the AC voltage supply to be rectified.
With the aim of the same operating conditions for the magnetic core, it imposes:

$$\psi = \psi^* \tag{18}$$

that means:

$$E^* = E\frac{1}{\sqrt{1+\varepsilon^2}}\frac{\pi}{2\sqrt{2}}\frac{1}{\sqrt{\varepsilon^2 + \frac{2}{9(1+4\varepsilon^2)}}} < E \tag{19}$$

where it has been taken into consideration the (15) and (17).

If it considers the over-unit values of ε, for the AC electromagnets, for instance $\varepsilon \geq 2$, the (19) will become:

$$E^* \leq 0.2479E \tag{20}$$

If it analyses the pulse values of the attraction force of the electromagnet supplied with double rectified voltage, p', and considering $\varepsilon \geq 2$, results:

$$p' \leq 0.0129 \tag{21}$$

with the less values respect to the optimal value of the AC single-phase electromagnet with screen turns, see (4):

$$p = 0.7853 \tag{22}$$

It can affirm that with AC single-phase electromagnets supplied with double rectified voltage, results the elimination of the vibrations of the movable armature, and it could give up of the screen turns placement on the magnetic core poles. Beside technological simplification for the magnetic core achievement for these kind of electromagnets it obtains higher values for the minimum attraction force at the same values of the average attraction force and the operating advantages of assemble behaviour.

4. CONCLUSIONS

Making a comparison for the AC single-phase electromagnets operating type U-I between AC voltage supply and double rectified voltage supply, by evaluation the pulses of the resultant attraction force it confirms the possibility of screen turns elimination in the case of coil supplied with double rectified voltage, that means the construction simplification of the electromagnet core.

It defines the RMS value of the double rectified voltage supply taking into account the parameters of the electromagnet coil. The conclusions are validity for all type of the AC single-phase electromagnets when the coil is supplied with double rectified voltage.
The technological and construction simplification regard to magnetic core achievement fully counterbalance the cost of the rectifier bridge.

References

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