PRECISE PARAMETERS IDENTIFICATION OF THE ASM SUBSTITUTING CIRCUIT

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ABSTRACT

The paper deals with the precise identification of the substituting circuit parameters of the asynchronous machine. The substituting circuit is taken in the shape of the Γ-circuit, not T-circuit. The identification of the machine AVM 112M06-523, 2,2kW, 2p = 6 is shown. The identification method is based on the synthesis of the experimental methods, the nominal values, and theoretical procedures.

1. INTRODUCTION

The substituting circuit in the shape of the classic T-circuit usually has been used for the asynchronous machine more than one century. However, the calculation of the torque characteristics from the T-circuit is very difficult. This solution leads to the complicated algebraic expression. In literature the usual procedure is following: T-circuit is intentionally *non-exactly* substituted by the Γ-circuit with the help of the *non-equivalent* circuit operations, see e.g. [1]. The efforts also exist about more precise recalculation of the T-circuit to the Γ-circuit but these results are controversial and disputed, see e.g. [1]. The honest departure from the rule is [3], where is used the precise recalculation from the formal mathematical point of view, however, the procedure is not justified with the actual physical ideas. This is the reason that this solution seems “too exotic” for the technical public. The precise analysis of the recalculation with the mathematical evidences and physical interpretation are given in [4]. The evidence are introduced here that the Γ-circuit is absolutely fully valuable and accurate, and that the reason for T-circuit usage does not exist.

2. SUBSTITUTING CIRCUIT

The substituting circuit in the shape of the Γ-circuit is shown in Fig.1. If comparing it with T-circuit, the great advantage of Γ-circuit is decreasing of the number of the unknown demanded parameters by number one because of formal point of view the primary leakage inductance is missing. Let us emphasize, that this fact absolutely does not negative influence to the generality of this Γ-circuit, see [4].

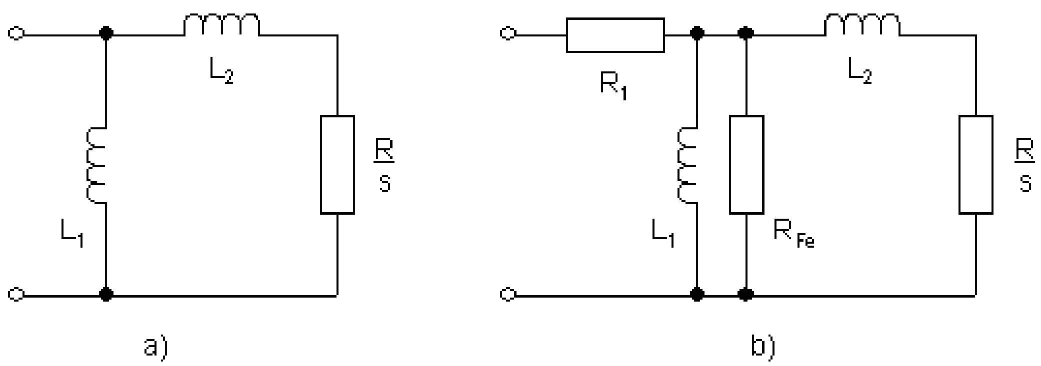

Fig. 1: Substituting Γ-circuit for the ASM. a) For ideal machine without losses. b) With the losses in the stator copper and iron.

3. CALCULATION METHOD

By the experimental way, from the voltage, current, and power in the one phase of the ASM it is possible to determine input impedance of the machine in the two different working points A, B. This means, it is possible to determine two pairs of the values R_A L_A, and R_B, L_B, see Fig.2b).

Then, the identification method is following: to find out such values of the circuit elements R_1, L_1, R_{Fe}, L_2, R so that the input impedance in Fig.2a) is identical to the experimentally determined impedance in the Fig.2a).

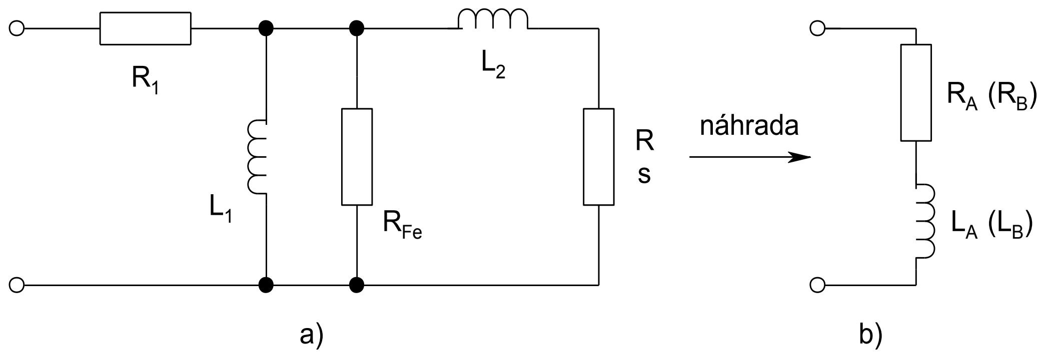

Fig. 2: The input impedance of the Γ-circuit a) must be the same as the experimental impedance b)

The stator winding resistance R_1 is taken as well known value which can be very easily measured.

In accordance to the Fig.2a) the algebraic complex term must be created for the input impedance. This theoretical impedance must be compared to the experimental gotten impedances in Fig.2b). The experiment must be realised in two working points A, B at two measured slips s_A, s_B, see Tab.1. So we get two equations containing complex terms. If comparing separately theirs real, and imaginary parts, so we get the system of four equations with four unknown circuit elements L_1, L_2, R_{Fe}, R.

The system of four equations can be solved by usual elimination method. If we choose the elimination order R, L_2, L_1, R_{Fe}, for the elimination, then the last eliminated equation, for unknown variable R_{Fe}, has the form

$$\sum_{i=0}^{14} R_{Fe}^{i} \cdot K = 0 \tag{1}$$

where K_i are the general constants created by the algebraic combination of the parameters R_1, R_A (R_B), L_A (L_B), s_A (s_B), and the frequency ω.

Unfortunately, equation (1) is algebraic equation of 14th order (!). It contains all powers of the order from zero up to 14th. This equation is unsolvable by algebraic way. The numerical solution methods are possible, however, the convergence of the iteration methods strongly depends on the result estimation, and on the convergence area knowledge. From the mathematics point of view the numerical solving is possible, from the practice point of view it is unusable.

Thus, it is possible to recommend the following escape from this difficult situation:

The parameter R_{Fe} will be taken as the well known value. Scilicent, this value can be relative easily determined from the idle ran regime or it can be estimated based on the experiences. In this case, the number of the equations decreases with number one, and astonishingly, the elimination method leads to the *quadratic* equation only. Then the solution has the following form:

$$R = \frac{\omega \; L_A L_1 L_2 s_A - L_1 K_1 - L_2 K_1}{L_A R_{Fe} + L_1 R_X - L_1 R_{Fe}} \tag{2}$$

$$L_2 = \frac{L_1^2 K_4 - L_1 K_3}{L_1^2 K_2 - L_1 2 K_4 + K_3} \tag{3}$$

$$L_1 = \frac{K_{10} \pm \sqrt{K_{10}^2 - K_9 K_{11}}}{K_9} \tag{4}$$

where K_1 up to K_{11} are the general constants created by the algebraic combination of the parameters R_1, R_A (R_B), L_A (L_B), s_A (s_B), and the frequency ω, see the Appendix.

4. MEASURED RESULTS

The identification has been made for asynchronous machine AVM 112M06-523, 2p = 6, 500V, 2,2kW, 50Hz. From Tab.1 it is seem that the motor was measured in six working points, i.e. at six different load torques, but always at the nominal voltage. The slips, voltages, currents and active powers were measured. Eight different couples A, B were chosen from six measured points. The identification has been made for all eight couples. By theoretical way, each of eight calculations would have to give the same results. With regard to the temperature sensitivity of resistances R_1, R, the individual results differed in order of units %. Because of that difference, these eight results were averaged. The average values are introduced in Tab.2.

Note: With regard to the vector control of the ASM, the measured working points have to be taken closely to the nominal point. The points lying behind critical slip, including s = 1, are not suitable.

$Z_{vst,A}(Z_{vst,B}) = R_A(R_B) + j\cdot\omega_A(\omega_B)$			
M	s_A (s_B)	R_A (R_B)	ωL_A (ωL_B)
[Nm]	[-]	[Ω]	[Ω]
12	0,025	53,909	68,173
16	0,034	54,762	55,920
20	0,043	52,296	46,181
24	0,054	49,987	37,385
28	0,067	46,013	29,845
32	0,081	41,724	24,819

Table 1: Six measured points used for the identification.
Motor AVM 112M06-523

Stator resistance	R_1	5,30	Ω
Equivalent iron loss resistance	R_{Fe}	803,00	Ω
Rotor resistance transformed to stator	R	4,43	Ω
Reactance/inductance of stator	ωL_1/ L_1	105,00/0,33	Ω/H
Leakage reactance/inductance transformed to stator	ωL_2/ L_2	10,96/0,03	Ω/H

Table 2: Identified parameters of the machine AVM 112M06-523

5. CONCLUSION

The paper refers to the identification process of the substituting Γ-circuit of the asynchronous motor. The identified parameters were used to the theoretical calculation of the torque characteristics. The computed characteristics almost agree with the experimental one. The small deviations can be mainly explained with the sensitivity of the critical torque to the stator resistance change (with the temperature), skin-effect e.g. The similar problems also appear at the T-circuit.

ACKNOWLEDGEMENTS

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APPENDIX

$$K_1 = R_{Fe} R_X s_A$$

$$R_X = R_A - R_1$$

$$K_2 = \omega R_X^2 - 2\omega R_{Fe} R_X + \omega L_A^2 + \omega R_{Fe}^2$$

$$K_3 = \omega L_A^2 R_{Fe}^2 + R_{Fe}^2 R_X^2$$

$$K_4 = \omega L_A R_{Fe}^2$$

$$K_5 = R_{Fe} R_X R_Y \left(1 - \frac{s_A}{s_B}\right) + R_{Fe}^2 R_X \frac{s_A}{s_B} - R_{Fe}^2 R_Y$$

$$R_Y = R_B - R_1$$

$$K_6 = L_A R_{Fe}^2 R_Y - L_B R_{Fe}^2 R_X \frac{s_A}{s_B}$$

$$K_7 = K_5 - \omega L_A L_B R_{Fe} \left(1 - \frac{s_A}{s_B}\right)$$

$$K_8 = \omega L_A \frac{s_A}{s_B} (R_Y - R_{Fe}) + \omega L_B (R_{Fe} - R_X)$$

$$K_9 = K_2 K_5 + K_4 K_8$$

$$K_{10} = \frac{1}{2} (K_3 K_8 + 2 K_4 K_5 - K_2 K_6 - K_4 K_7)$$

$$K_{11} = K_3 K_5 - K_4 K_6 - K_3 K_7$$