TEMPERATURE SENSITIVITY OF PULL-OUT TORQUE TO STATOR RESISTANCE OF THE INDUCTION MACHINE

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ABSTRACT

The paper relate to results reached at the parameters identification of the induction motor substituting circuit in the form of the Γ-network, see [1]. It is to see that the coincidence of the measured and calculated torque characteristic is very sensitive to the resistance values of the stator and rotor winding, i.e. to their temperature.

1. INTRODUCTION

There is defined the identification process of the substituting circuit parameters of the asynchronous machine in the paper [1]. The confirmation of the identified parameters consists of the comparing of the computed characteristic and the experimental ones see [2]. The both characteristics have been practically identical. These deviations are not cause by using the substituting circuit in the shape of the Γ- network. The differences between the experiments and calculations can be fully explained with the characteristics sensitivity to the stator and rotor resistance, and their changes with the temperature.

2. TORQUE CHARACTERISTIC OF ASYNCHRONOUS MACHINE

The substituting circuit in the shape of Γ- network is shown in Fig.1.

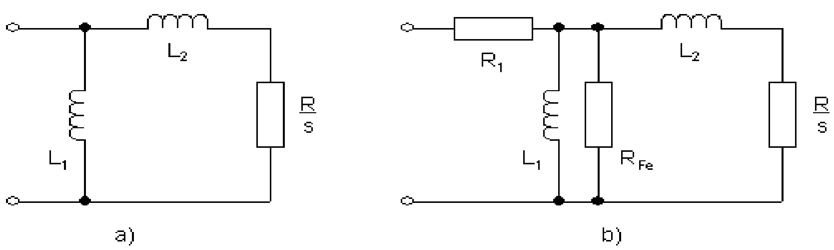

Fig.1: Substituting Γ- network for the ASM. a) For ideal machine without losses. b) With the losses in the stator copper and iron.

The identification has been made for asynchronous machine AVM112M06-523, 2p=6, line to line voltage 500V, phase current 4.19A, 2.2kW, 50Hz.

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	$\omega L_1/ L_1$	105,00/0,33	Ω/H
Leakage reactance/inductance transformed to stator	$\omega L_2/ L_2$	10,96/0,03	Ω/H

Table 1: Identified parameters of the machine AVM 112M06-523

Based on the substituting Γ-network, according to Fig.1b), it is possible to calculate the precise working characteristics of the ASM. The torque is given by equation (1):

$$T = \frac{3U^2 R\, p\omega s}{\left[\left(1+\frac{L_2}{L_1}\right)R_1\omega s + \left(1+\frac{R_1}{R_{\mathrm{Fe}}}\right)R\omega\right]^2 + \left[\left(1+\frac{R_1}{R_{\mathrm{Fe}}}\right)\omega^2 L_2 s - \frac{R_1}{L_1}R\right]^2} \tag{1}$$

The experimentally determined and calculated torque characteristic is shown in Fig.2.

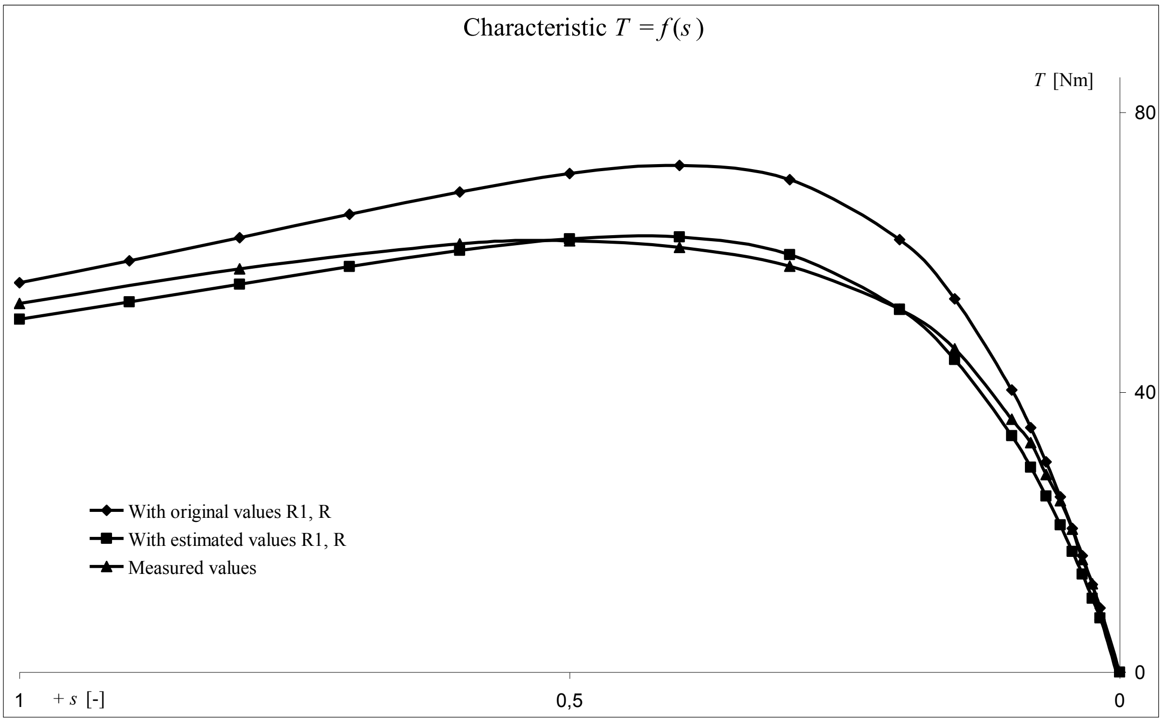

Fig.2 Torque of the motor AVM 112M06-523

The temperature dependences of the resistances R_1, R and the sensitivity of the T(s) characteristic to the change of resistances R_1, R are the reason why the differences exist between the measured and calculated characteristics. Because of it, three different curves are shown in Fig.2:

- Measured curves
- Curves calculated with the original values R_1, R identified at the nominal point
- Curves calculated with the higher values R_1, R, estimated with regard to the higher winding temperature (in the motor regime, not generator regime).

Because of it, the following chapter will be focused on the sensitivity analyse of the pull-out torque to the resistance of the stator winding.

3. TEMPERATURE DEPENDENCE OF PULL-OUT TORQUE

Derivation of the equation (1) according to slip and by neglecting of the stator resistance will be given equation (2) for pull-out slip s_{crit}:

$$s_{crit} = \pm \frac{pR}{\omega L_2} \tag{2}$$

From equation (2) to equation (1), the following relationship for the pull-out torque T_{crit} is obtained:

$$T_{crit} = \frac{3U^2 L_2 p}{\left[R_1\left(1+\frac{L_2}{L_1}\right)+\omega L_2\right]^2+\left[\omega L_2 - R_1\frac{L_2}{L_1}\right]^2} \tag{3}$$

The dependence of the pull-out torque on stator resistance, according to the equation (3), is shown in Fig. 3.

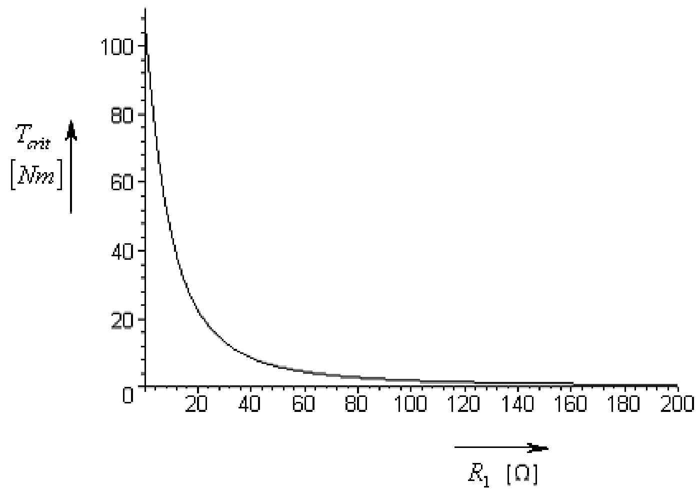

Fig.3. Pull-out torque according to stator resistance

From Table 1 and from equation (3) is given pull-out torque, M_m = 67 Nm, of the asynchronous machine AVM112M06-523.

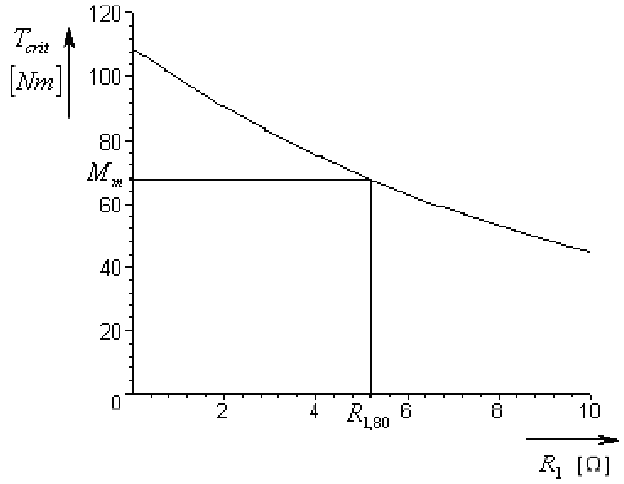

Fig.4. Pull-out torque according to stator resistance of the asynchronous machine AVM112M06-523

There is shown, in Fig.4, with higher stator resistance the pull-out torque is falling down. If the stator resistance is neglected, the value of the pull-out torque will be, according the equating (3), $T_{\text{crit}} = 109$ Nm. The value $T_{\text{crit}} = 67$ Nm of pull-out torque of the asynchronous machine AVM112M06-523 is given at the value $R_{1,80}$ of the stator resistance.

For the calculation of the sensitivity of pull-out torque according to stator resistance is necessary to differentiate the equation (3) according to R_1.

$$\frac{dT_{crit}}{dR_1} = -\frac{3U^2 L_2 p_p \cdot (2R_1 K_1 + K_2)}{\left[R_1^2 K_1 + R_1 K_2 + K_3\right]^2}, \qquad (4)$$

where $K_1 = \left[\left(1 + \frac{L_2}{L_1}\right)^2 + \left(\frac{L_2}{L_1}\right)^2\right]$,

$K_2 = 2\omega L_2$,

$K_3 = 2\omega^2 L_2^2$.

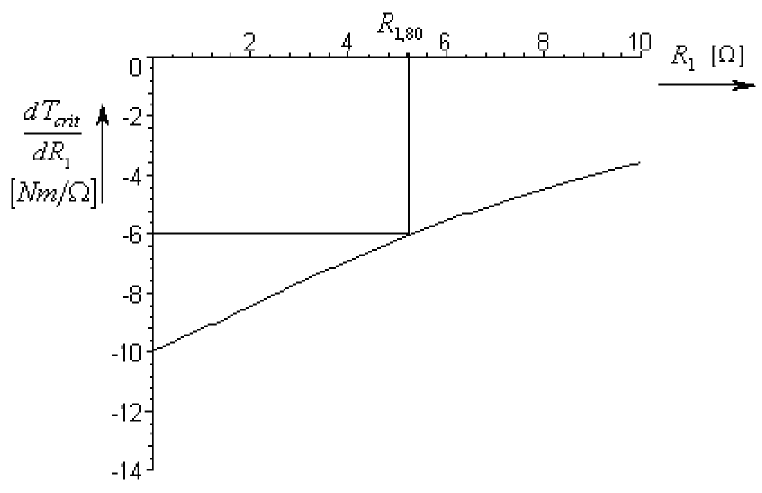

Fig.5. Differentiation of the pull-out torque according to stator resistance of the ASM AVM112M06-523

From Fig.5 is obtained the following relationship:

$$\frac{dT_{crit}}{dR_1} = -6 \left[\frac{Nm}{\Omega}\right] \tag{5}$$

From equation (5) it is to see, that the pull-out torque sensitivity on the stator resistance is −6Nm/Ω. When consider the temperature rise $\Delta\vartheta = 80\text{K}$, It is possible the equation (5) to recalculate to the following shape

$$\frac{dT_{crit}}{d\vartheta} = -0{,}4 \left[\frac{Nm}{K}\right]. \tag{6}$$

From equation (6) it is to see, that the pull-out torque sensitivity on the temperature is −0.4Nm/K.

5. CONCLUSION

There is shown, in Fig.2, that the experimentally determinated characteristic and the calculated characteristic are different. Measurement of the torque has been made "manually", i.e. relative slowly. This is the reason why the motor temperature arose a lot during the measurement, at the great slips $s \rightarrow 1$.

- In area of the pull-out torque, the following relations are valid:

  $I \cong 4I_n \;\Rightarrow\; P_{\mathrm{Cu}} \cong 16P_{\mathrm{Cu},n} \;\Rightarrow\; \vartheta_{\mathrm{Cu}} > \vartheta_{\mathrm{Cu},n} \;\Rightarrow\; R_1 > R_{1,n},\, R > R_n.$

- In area of the starting torque, these relations are valid:

  $I \cong 5I_n \;\Rightarrow\; P_{\mathrm{Cu}} \cong 25P_{\mathrm{Cu},n} \;\Rightarrow\; \vartheta_{\mathrm{Cu}} >> \vartheta_{\mathrm{Cu},n} \;\Rightarrow\; R_1 >> R_{1,n},\, R >> R_n$

The differences can be fully explained with the thermal dependences to the stator and rotor resistance, and their changes with the temperature.

The calculation of torque characteristic, according to equation (1), is not utterly exact. The stator resistance is count wrong as a constant value. This condition is approximately real in the "linear area" of torque characteristic, but not absolutely. In area of pull-out torque and starting torque, isn't this condition absolutely accomplished! This is main reason of the differences between the experiment and the calculation.

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REFERENCES

[1] Běloušek J., Patočka M.: Identifikace parametrů asynchronního motoru. Sborník konf. EPVE 06, VUT FEKT Brno, listopad 2006

[2] Běloušek J., Patočka M.: Precise parameters identification of the ASM substituting circuit. Sborník konf. EDPE07, TU Košice, září 2007