COMPARISON BETWEEN A THREE PHASE AND A TWO PHASE INDUCTION MOTOR BUILT UP ON THE SAME CORE

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Abstract. In the paper a comparison between a three-phase and a two-phase induction machine is presented. Both machines are built up on the same iron core. They have the same stator number of slots, number of turns per coil and rotor squirrel-cage winding. The motor parameters, currents and torques are computed, evincing, the differences between the induction machines.

Key words: two-phase induction machine, three-phase induction machine, field harmonics, electromagnetic torque

INTRODUCTION

The induction machine is the most frequently used electrical device in operations with different degrees of complexity, being reliable, robust and in the same time having a competitive price. In the electrical operations where the engine is supplied from a network with a constant frequency and tension, the two-phase motor is out of place due to the fact that the two-phase networks do not exist.

The usage of static sources controlled by variable tension and frequency makes possible the usage of the two-phase induction machine (MAB) in operations with variable rotation. Taking into account the competitivity of the electronic convector of power, the competitivity degree becomes very important for MAB in comparison to the three-phase induction machine (MAT).

We encounter a large variety of aspects that can be debated on concerning this comparison. Thus, in order to offer a valid comparison, between the two types of induction motors, two-phase and three-phase, it was chosen the solution of the motors realized on the same iron core with an identical squirrel cage rotor. The two motors have the same number of conductors in the statoric split and the same synchronism velocity. The number of phased enseriated coils, the number of spires, the winding factor and the relation rotor-stator factor.

THE MATHEMATICAL MODEL

The comparison to the tree-phase motor can have two distinct aspects:

1. There are compared the same orders of the harmonic.
2. There are compared the different order harmonics of the same importance.

In the first case, when the orders of the harmonic are the same, assuming that the two statoric windings are placed on the same iron core of the three-phase machine, there results the equality of the winding factors and the relation of the useful inductances for a statoric area is,

$$ {}^{\varphi}L^{*}_{s\rho} = \frac{2}{3}\left(\frac{W_s^{*}}{W_s}\frac{{}^{\varphi}k^{*}_{w}}{{}^{\varphi}k_{w}}\right)^2 \cdot {}^{\varphi}L_{s\rho} \tag{1} $$

where,

$$ {}^{\varphi}L^{*}_{s\rho} = \frac{\mu_0}{\delta'}\frac{m_1^{*}lr}{p\pi}\left(w_s^{*}\frac{{}^{\varphi}k_w^{*}}{\varphi}\right) $$ statoric leakage inductance for MAB, and

$$ {}^{\varphi}L_{s\rho} = \frac{\mu_0}{\delta'}\frac{m_1\,lr}{p\pi}\left(w_s\,\frac{{}^{\varphi}k_w}{\varphi}\right) $$ rotoric leakage inductance for MAT.

Hypothetically when the windings have the same number of spires winded on a coil, s_b and the same number of pole pairs, the relation for the number of spires is,

$$ \frac{W_s^{*}}{W_s} = \frac{q^{*}}{q} = \frac{3}{2} \tag{2} $$

If mmf shape factors is same, then,

$$^{\varphi}k^{*}_{y} = {}^{\varphi}k_{y} \tag{3}$$

and relation between distribution factors is,

$$\frac{^{\varphi}k^{*}_{q}}{^{\varphi}k_{q}} = \frac{2}{3}\frac{\sin(\varphi q^{*}\frac{\pi}{Z_S})}{\sin(\varphi q\frac{\pi}{Z_S})} \tag{4}$$

Taking into account that the winding factor is $^{\varphi}k_{w} = {}^{\varphi}k_{y} \cdot {}^{\varphi}k_{q}$, after a mathematical calculus, the relation of the useful inductances become,

$$\frac{^{\varphi}L^{*}_{S\rho}}{^{\varphi}L_{S\rho}} = \left(\frac{2}{3}\frac{\sin(\varphi q^{*}\frac{\pi}{Z_S})}{\sin(\varphi q\frac{\pi}{Z_S})}\right)^2 \tag{5}$$

Where, I wrote (*) for the magnitudes corresponding to the two-phase winding, and $\varphi = p$ for the fundamental harmonics of the same order, for the two machines.

In the second variant of comparison, there will be taken into consideration the useful inductances corresponding to the same constant value 'a' in the harmonic orders. In the case of a particularization for the first harmonic order, *a=1*. In this situation $\nu = 7p$, $\nu^{*} = 5p$ and their relation is,

$$\frac{\nu^{*}}{\nu} = \frac{5}{7} \quad \text{where} \quad \nu = p(2m_S a+1)\ si\ m_S = 3, \quad \nu^{*} = p(4a+1) \tag{6}$$

Relation between inductances become,

$$\frac{^{5p}L^{*}_{S\rho}}{^{7p}L_{S\rho}} = \frac{2}{3}\left(\frac{5}{7}\frac{^{5p}k_y}{^{7p}k_y}\frac{\sin(\frac{5\pi}{4})}{\sin(\frac{7\pi}{6})}\frac{\sin(7p\frac{\pi}{Z_S})}{\sin(5p\frac{\pi}{Z_S})}\right)^2\frac{7\sin(\frac{7p\alpha_{cs}}{2})}{5\sin(\frac{5p\alpha_{cs}}{2})} \tag{7}$$

In conclusion we can say, as in the case of the two-phase winding, that the first possible harmonic orders have lesser values and consequently, they have higher amplitudes, as it results from the useful inductances ratio (7). It is highlightned the fact that in both instances, namely the two-phase winding and the three-phase one, the calculation steps are the same and the differences are minor. Therefore, the results obtained in the case of the three-phase machine can be generalized for the treatment of the two-phase machine, too.

In order to fulfill this comparison, we have chosen a normalized MAT of the type 132S; 5,5kW; 1500 rot/min, whose parameters are know (Viorel 1978). The MAB parameters have been obtained through usual ration in design (Cioc 1976, Craciunas 2002).

It has been determined a mathematical model which has been implemented on the computer with the aid of Borland C++, program, and the comparison between the two machines has been made between the fundamental harmonics and the main space harmonics of the currents and the torques with the slip in a stationary regime. For the calculation of the statoric and rotoric currents, there have been used the following voltage equations,

$$\underline{U}_S = \left[R_S + j\omega_S\left(L_{S\sigma} + L_S\right)\right]\underline{I}_S + j\omega_S\sum_{\nu}\left\{{}^{\nu}M'_{RS}\,{}^{\nu}\underline{I}_R + {}^{\nu-Z_S}M'_{RS}\,{}^{\nu-Z_S}\underline{I}_R + {}^{\nu+Z_S}M'_{RS}\,{}^{\nu+Z_S}\underline{I}_R\right\} \tag{8}$$

$$0 = \left[R_R + j^{\nu}s\omega_S\left(L_{R\sigma} + \sum_{\nu}{}^{\nu}L_R\right)\right]{}^{\nu}\underline{I}_R + j^{\nu}s\omega_S\,{}^{\nu,\nu}M'_{SR}\,\underline{I}_S \tag{9}$$

$$0 = \left[R_R + j^{\nu-Z_S}s\omega_S\left(L_{R\sigma} + {}^{\nu-Z_S}L_R\right)\right]{}^{\nu-Z_S}\underline{I}_R + j^{\nu-Z_S}s\omega_S\frac{\lambda_S}{2}{}^{\nu,\nu-Z_S}M'_{SR}\,\underline{I}_S \tag{10}$$

$$0 = \left[R_R + j^{\nu+Z_S}s\omega_S\left(L_{R\sigma} + {}^{\nu+Z_S}L_R\right)\right]{}^{\nu+Z_S}\underline{I}_R + j^{\nu+Z_S}s\omega_S\frac{\lambda_S}{2}{}^{\nu,\nu+Z_S}M'_{SR}\,\underline{I}_S \tag{11}$$

$$0 = \left[R_S + j^{-Z_R}\omega_S\left(L_{S\sigma} + {}^{-Z_R}L_S\right)\right]{}^{-Z_R}\underline{I}_S + j^{-Z_R}\omega_S\sum_{\nu}{}^{\nu+Z_R}M'_{RS}\,{}^{\nu}\underline{I}_R + j^{-Z_R}\omega_S\frac{\lambda_R}{2}\sum_{\nu}{}^{\nu+Z_R}L_S\underline{I}_S \tag{12}$$

$$0 = \left[R_S + j^{Z_R}\omega_S\left(L_{S\sigma} + {}^{Z_R}L_S\right)\right]{}^{Z_R}\underline{I}_S + j^{Z_R}\omega_S\sum_{\nu}{}^{\nu-Z_R}M'_{RS}\,{}^{\nu}\underline{I}_R + j^{Z_R}\omega_S\frac{\lambda_R}{2}\sum_{\nu}{}^{\nu-Z_R}L_S\underline{I}_S \tag{13}$$

For MAT the values used for the design of the diagram have been taken from literature, (Viorel 1978). In Figure 1 there are shown the fundamental statoric currents for the two machines. With (*) there have been written the MAB values. In Figure 2 there are shown the currents from the rotor for the fundamental harmonic, In Figure 3 and Figure 4, there are shown the rotoric currents for the first two superior harmonics, for MAB respectively for MAT. After the calculus relation for an harmonic, (6), the two machines present the same harmonic order for the fundamental, $\nu = p$ and different orders for the superior harmonics, $\nu = -3p,\ 5p$, for MAB and

$\nu = -5p,\ 7p$, for MAT. Thus, the comparison was made on the same diagram for the fundamental rotoric current.

Another facility for the suggested program is that of determining the electromagnetic torques for different harmonic orders, with the aid of the calculus formulae (Craciunas 2002). In Figure 5 there are shown the fundamental electromagnetic torques of the two machines.

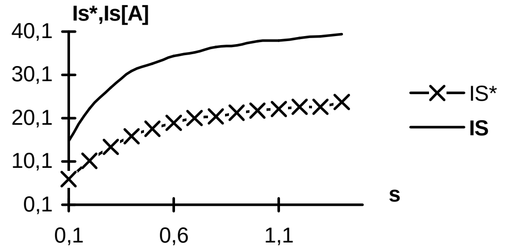

Fig.1

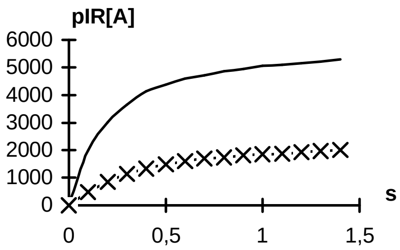

Fig.2

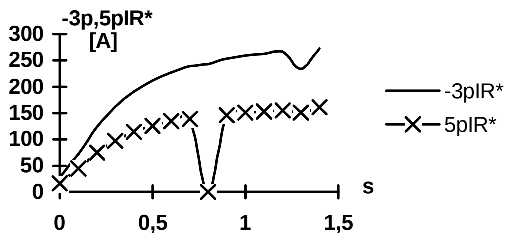

Fig.3

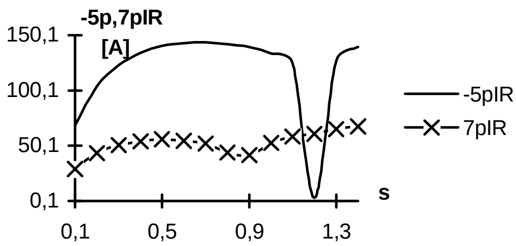

Fig.4

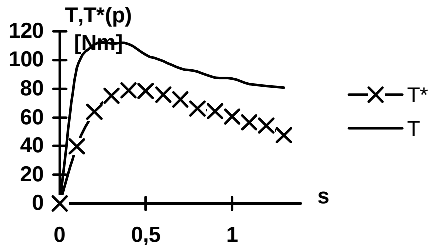

Fig.5

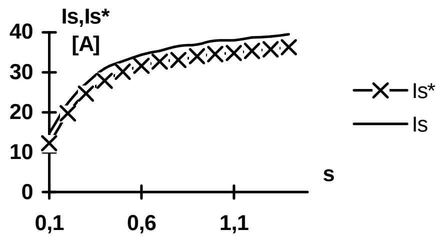

Fig.6

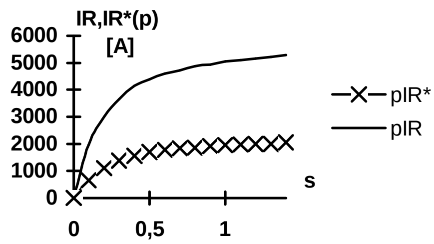

Fig.7

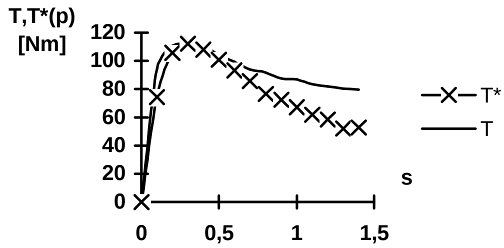

Fig.8

The resulted diagram's highlighten the weak performances of the two-phase induction machine made on the iron core of a three-phase induction machine. It is noticed that the stator and the rotor currents, as well as the fundamental electromagnetic torques are of a much lesser values than those of a three-phase machine. Also, the relation between the parameters value of the three-phase machine and those of the two-phase machine are higher than 1,5. This drawback for MAB can be adjusted through the modification of the main entry for the coiling in the stator (the resistance and the number of spires for the winding in the stator). Thus, if the resistance in the stator of the two machines is equal and has the value $R_S = 1{,}63\Omega$,and the number of spires, $w_S = 300$, we obtain other characteristics for the currents of the two windings, Figure 6 and Figure 7. For the fundamental electromagnetic torques we obtain Figure 8.

In order to evaluate the operation possibilities of an electric engine, there is always indicated its power. But, by indicating this parameter, even when there is also mentioned its corresponding rotation, it is not always enough in order to appreciate the behavior the engine-charge ensemble. Therefore, in order to define the performances of the electrical machine, particularly for the MAB and MAT engines, it is necessary to determine some very important parameters that contribute to the well functioning of a machine. Thus, for the two examples given above, it was made a power estimation, Table 1, where there are given the results of the mathematical calculations obtained for the power and the output factor. (Cioc 1976.)

Table 1

	$R_S = 2{,}43\Omega$ (MAB)		$R_S = 1{,}63\Omega$ (MAB)	
	$\cos\varphi$	η	$\cos\varphi$	η
MAB	0,737	0,759	0,872	0,872
MAT	0,865	0,857	0,865	0,857

As a conclusion to the facts illustrated in the Table, we can notice that MAB has the power factors, as well as the output factor lesser than at MAT. These drawbacks have been corrected by modifying the value of the winding stator MAB, resistance, respectively $R_S = 1{,}63\Omega$. In this case, the values obtained are higher than those of MAT.

CONCLUSIONS

The conclusions of this paper are:

- In the two-phase winding the first possible harmonic orders have lesser values and they have higher amplitudes, a fact that results from the useful inductance relation of the statoric area.

- For the two-phase winding, as well as for the three-phase one, the calculus steps are the same and the differences are minor, therefore the results obtained in the case of the three-phase rotor can be generalized to include the corresponding treatment of the two-phase engine, too.

- The MAB built on the iron core of a MAT with an identical squirrel cage rotor, determines some characteristics and consequently, weaker performances than the three-phase machine, but, these drawbacks can be corrected through a well done design of MAB (by modifying the statoric resistance and the number of spires from the stator), obtaining in this way similar performances to a MAT.

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