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LOSS ESTIMATION AND PARAMETERS CALCULATION OF A 7.5kW INDUCTION MACHINE

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ABSTRACT

This paper presents the Loss estimation and parameters calculation of 10hp three phase induction machine. The data obtained will enhance the activities of the motor and FEM designers in proposing the electromagnetic and thermodynamic model of AC induction machines. To achieve the purpose of this paper, we have assumed the efficiency of an induction machine to be 85.7 percent and a power factor of 0.87. The effect of various machine parameters such as the resistances of stator and rotor, rotor current, induction machine losses are also presented in this paper.

KEYWORDS: Loss Estimation, Losses, Power Factor, Parameters

INTRODUCTION

These days, more than 90% of all motors used in industry worldwide are AC induction motors, they are the preferred instruments of choice due to their low cost and rugged construction [1, 2]. The simple and rugged construction of the induction motor contributes to its reliability and makes it attractive for shipboard and other numerous applications. However, the design problems like electromagnetic and thermal issues have not allowed the machine to perform optimally due to the inherent losses arising from the problems. This paper attempts to examine some of the losses and estimate the values within allowable schemes as it studies this 7.5kW machine represented in figure (1) below.

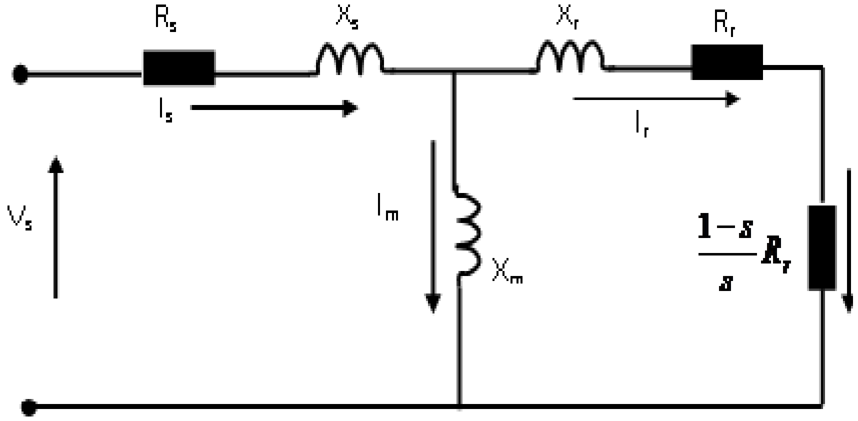

Figure 1: Equivalent Circuit of the 7.5kw Induction Machine

LOSS ESTIMATION OF THE 7.5kw INDUCTION MACHINE

The values of the parameters of this 400V machine having 4 poles whose synchronous and measured speed are 1500 rpm and 1440 rpm with rated current 13.5 A analyzed in this work are given in Table 1 below.

Table 1: Induction Machine Parameters Obtained from Calculation

7.5kVA Induction Motor Parameters	Calculated Value
Stator Current (I_s)	13.4699 A
Rotor Current (I_r)	11.6627 A
Stator Resistance (R_s)	0.7384 Ω
Rotor Resistance (R_r)	0.7402 Ω
Stator Core Loss Current (I_c)	0.3393 A
Magnetizing Current (I_m)	5.5430 A
Excitation Current (I_0)	5.5534 A
Stator Core Loss Resistance ($R_c = R_m$)	680.58 Ω
Rotor Leakage Inductance (L_r)	0.003045 H
Stator Leakage Inductance (L_s)	0.003045 H
Magnetizing Reactance (X_m)	38.9872 Ω
Slip (s)	4.0%
Rotor Frequency (f_r)	2.0 Hz
Shaft Load Torque (T_{sh})	44.401 N-m

The loss estimation of this 10HP induction machine has also been summarized in table (2) while formulas for some of the calculations are provided herein, hence, the results obtained here followed careful usage of these formulas shown below.

Input Power

$$P_{in} = 3V_s I_s Cos\theta \qquad (1)$$

The input power of the induction machine which ordinarily should be $8137.2\,\text{W}$ has because of the calculation arising from the circuit configuration becomes $7953.1\,\text{W}$.

Efficiency Calculation

$$\eta = \left(1 - \frac{P_{losses}}{P_{in}}\right) * 100\% \qquad (2)$$

Losses Calculation

$$P_{losses} = P_{STAcuL} + P_{ROTcuL} + P_{STAcore} + P_{FRIwin} + P_{STR} \qquad (3)$$

The Shaft Load Torque

$$T_{Sh} = \frac{P_{out}}{\omega_{in}} \quad (Nm) \qquad (4)$$

Air Gap Power

$$P_{AG} = 3I_r^2 \frac{R_r}{s} \tag{5}$$

Per-Phase Stator Core Loss Resistance

$$R_c = \frac{V_s}{I_c} \tag{6}$$

Per-Phase Stator Magnetizing Inductance

$$L_m = \frac{V_s}{2\pi f I_m} \tag{7}$$

Based on IEEE 1112-B standard [3], the P_{STR} value at 1 kW is 2.5% of the full-load input power, dropping at 10kW to 2%, at 100kW to 1.5%, at 1000kW to 1%, and at 10MW to 0.5% as reported in [4, 5], the stray load loss and rotational losses can be calculated .

Since the machine under study here is a 7.5 kW ≈ 10 hp machine, therefore,

$$P_{STR(IEEE)} = 7953.1 * 2.0\% = 159.062 \quad W \tag{8}$$

However, in the IEC 34-2 standard, these losses were not measured but were arbitrarily estimated to be equal to 0.5% of the full-load input power [4, 5], so that

$$P_{STR(IEC)} = 7953.1 * 0.5\% = 39.766 \quad W \tag{9}$$

A suggested solution in Ontario Hydro's simplified segregated loss method assumed a value for a combined windage, friction and core losses [5,6]. The study recommends that these combined losses be set to 3.5% of the input rated power which translates to:

$$P_{ROTaL} = 3.5\% * P_{in} \qquad W \tag{10}$$

Therefore, Obtained Rotational Losses

$$P_{ROTaL} = 3.5\% * 7953.1 \quad = 278.3585 \text{ W} \tag{11}$$

SEGREGATION AND ANALYSIS OF THE IM LOSSES

The estimated losses are summarized in table (2) below and presented in the following bar and pie charts for ease of understanding.

Table 2: Loss Segregation Obtained from Calculation

Losses Segregation	Calculated Value W)
Input Power (P_{in})	7953.1
Stator Copper Loss ($_{STAcuL}$)	401.9228
Rotor Copper Loss ($_{ROTcuL}$)	302.0438
Stator Core loss ($_{STAcore}$)	219.9939
Friction and Windage Losses ($_{FRIwin}$)	58.3663

Table 2: Contd.,

Rotational Losses ($_{ROTaL;\ Ontario}$)	278.3600
Stray Losses ($P_{strayIEEE\text{-}12B\ Standard}$)	159.0620
Total Losses (Watts)	1141.4
Output Power (P_{out})	6974.5

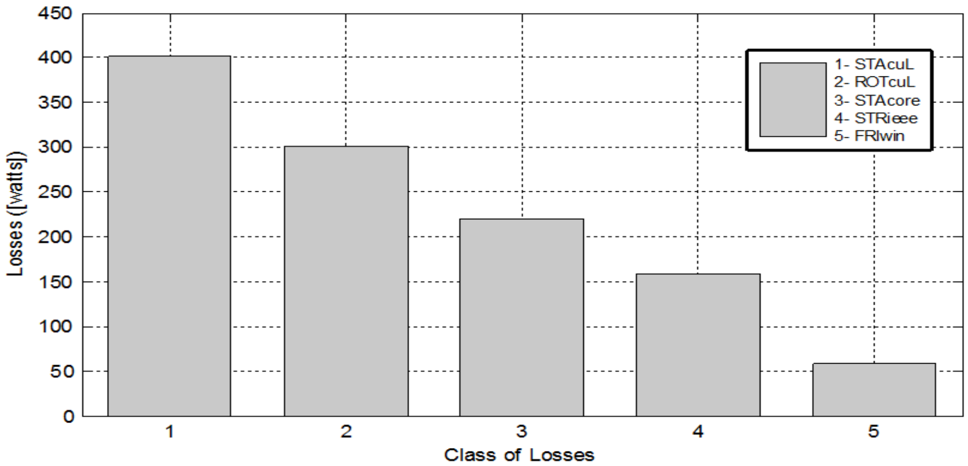

Figure 2: Bar Chart Representing Loss Segregation of 10HP Induction Machine

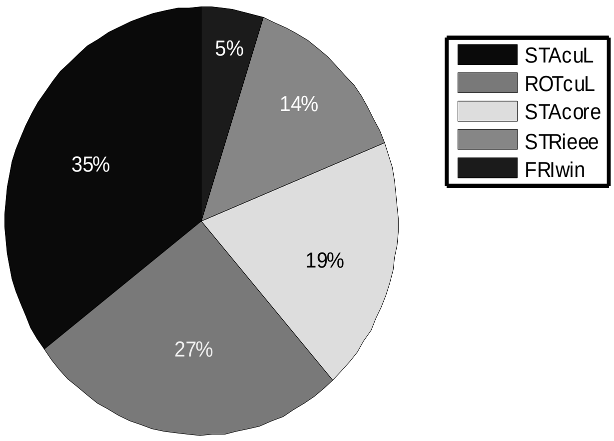

Figure 3: Pie-Chart Representing Loss Segregation of 10HP Induction Machine

In figure (2), it is clear that greater losses came from stator and rotor copper losses while friction and windage loss contributed a little. This is same in figures (3 and 4) with stator iron losses contributing three percent of the entire losses. A careful observation of figure (4) depicts that copper losses contributed about nine percent (9%), towards the losses while the rotational losses accounted for about five percent (5%). The last one, the stray loss, however accounted for one percent (1%). Hence, from the figure, it is very clear that about 15% of the total input-power into the 10hp induction machine is dissipated as losses and the balance, 85% represents the output power of the induction machine. In figure (5) it is shown that about seven percent (7%) of the available power is lost which is reflected in the fact that the input power became higher than the output power.

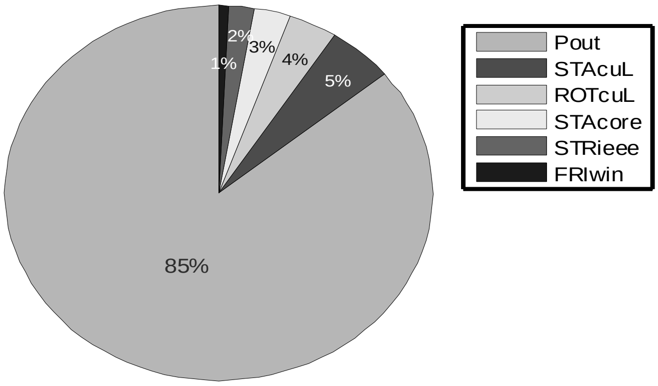

Figure 4: Pie-Chart Showing the Losses in Relation to the Output Power of 10HP IM

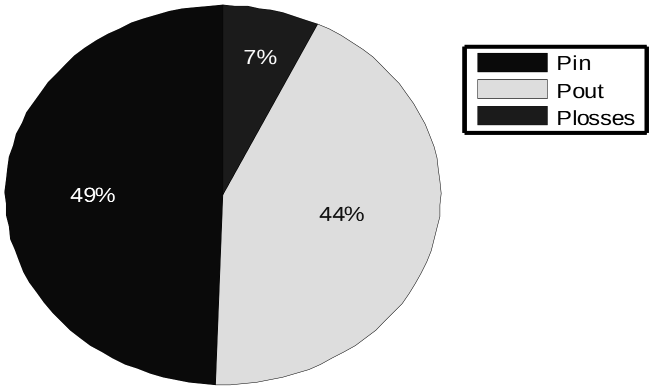

Figure 5: Pie-Chart Showing the Proportion of Lost Power in 10HP Induction Machine

SIMULATION RESULTS

The effects of the various motor parameters are represented by the lumped graphs of figure 6. Between the fourth and sixth second the instability as seen from the graph of the torque is clearly noticed from the curves of quadrature and direct axis rotor current.

There was a normal increase in the parameter values at the very start, after about 2s, the response curves came to a steady state except at the fourth to sixth seconds which invariably, did not have any effect on the rotor speed and the phase 'a' rotor current which never stabilized.

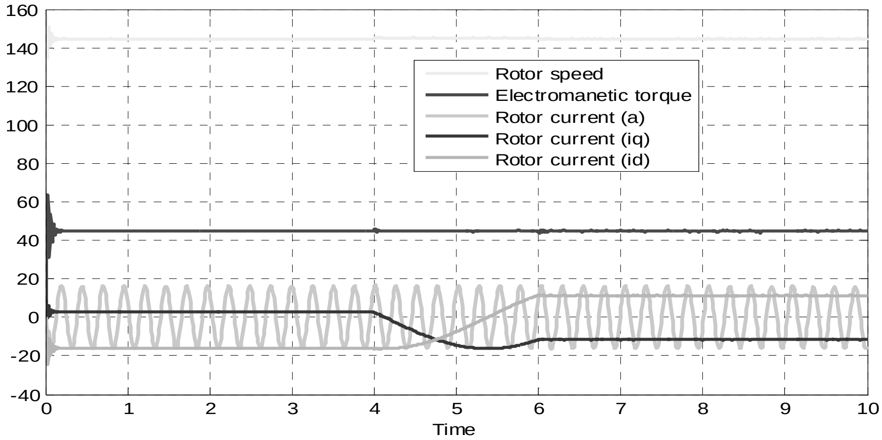

Figure 6: Graphs Showing the Effects of the Respective Parameters of the 10HP

CONCLUSIONS

The loss estimation and the parameter calculation of this machine have been looked into. For proper functioning of the electromagnetic and thermodynamic aspects of an industrial machine, the parameters evaluation should be given a prior attention so as to guard against unusual characteristics occasioned by over or under loading. The former brings about damage due to heating while the latter could result to inefficiency and under utilization. The crux had been an attempt to optimize the parameters taking cognizance of the losses as high efficient machine is the expected target.

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