ABSTRACT

The performance attributes of the 10hp induction machine is presented. From the features presented, there is no doubt as to whether this work tool is relevant in the scheme of events. To achieve this feat, the exercise is started by fundamentally deriving the systems operating parameters from the generally known equivalent circuit. The other complementing values were calculated from the machine parameters given, from which the various performance elements were simulated in matlab environment. The simulation results show a good response. At the operating point of 4 percent slip with about 13.5A as the stator current, the machine has a power factor of 0.87 and an efficiency of 85.7 percent.

Keywords--- Efficiency, performance, equivalent, power-factor

I. INTRODUCTION

Constant parameter models approach has been the traditional method of prediction of induction machine performances. It has however yielded good results for both the steady state and transient conditions [1]. This scheme is being found wanting on some instances relating to on-line starting and at times from in-rush current which gives rise to inaccurate electromagnetic torque. This is why the use of equivalent circuit approach is adopted as it is capable of taking care of these dual cases.

Induction machines are perhaps the most widely used of all electric motors. They are generally simple to build and rugged [2-3], offer reasonable asynchronous performance: a manageable torque-speed curve, stable operation under load, and generally satisfactory efficiency. Because they are so widely used, their operations and performances are worth understanding.

In addition to their current economic importance, induction motors and generators may find application in some new applications with designs that are not similar to motors currently in the market. An example is very high speed motors for gas compressors, perhaps with squirrel cage rotors, perhaps with solid iron or an aggregate of the two.

Because it is possible that future, high performance induction machines will be required to have characteristics different from those of existing machines, it is necessary to understand the basic principles and the characteristic features, and these are the objectives of this paper. It starts with a circuit analysis view of the induction machine. The model analyzed is used to explain the basic operations of induction machines. This analysis is strictly appropriate only for squirrel cage induction machine. However, it can easily but carefully be adjusted to deal with the wound-rotor machines, which eventually leads to an understanding of more complex machines cases.

II. DERIVATION OF THE PARAMETERS FROM EQUIVALENT CIRCUIT

The equivalent circuit methodology as shown in figure (1) is adopted. It is constructed by using the following set of induction machine parameters: $(R_s, X_s)$, $(R_m, X_m)$, and $(R_r, X_r)$. Each pair represents resistance and leakage reactance, respectively. The first pair deals with the stator parameter, while the third one deals with the rotor. The second pair of parameters takes care of magnetizing effects and models the generation of the air gap flux within the induction motor [4].
The resistance expression $\frac{1}{s}R_s$ is equivalent to load resistance connected to the secondary circuit of a transformer [5, 6]. With the given machine parameters and the equivalent circuit of figure (1), the characteristic graphs were obtained from the relations and analysis that follow; the stator current $I_s$ can be calculated from the input impedance $Z_{in}$ as

$$I_s = \frac{V_s}{Z_{in}} = \frac{V_s}{Z_{an} + Z_{bn}} \quad \text{..........} \quad (1)$$

But $Z_{bn} = jX_m \left( \frac{R_s}{s} + jX_r \right) \quad \text{..........} \quad (3)$

So that $Z_{bn} = \frac{\left( j^*X_m \right) x \left( \frac{R_s}{s} + jX_r \right)}{\left( j^*X_m \right) + \left( \frac{R_s}{s} + jX_r \right)}.$ \quad (4)

Hence,

$$I_s = \frac{V_s}{\left( R_s + jX_s \right) + \left( \frac{R_s}{s} + jX_r \right)} \quad \text{..........} \quad (5)$$

With the parameters given, the stator current is calculated in terms of slip as shown in equation (5.40) below, and from which the characteristic response curve of figure (6) is obtained.

$$I_s = \left( \frac{400 \Omega}{\left( j \left( \frac{28.8583}{s} - (37.2952) \right) \right)} \right) \quad \text{..........} \quad (6)$$

$$\left( 0.7384 + j0.9566 \right) + \left( j \left( 39.9438 + 0.7402 \right) \right)$$

The calculations so far bring the simplified equivalent circuit of figure (5.3) to figure (5.8) below from where further deductions take place looking at Thevenin’s equivalent values.

Now by using the venin expression for voltage $V_{Th}$, across the two major nodes, the torque $T_{RQ}$ is evaluated from

$$V_{Th} = \frac{\left( V_s \right) x \left( jX_m \right)}{\left( R_s \right) + j\left( X_s + X_m \right)}.$ \quad (7)$$

By substituting,

$$V_{Th} = \frac{\left( 400 / \sqrt{3} \right)x \left( j \times 38.9872 \right)}{\left( 0.7384 \right) + j\left( 0.9566 + 38.9872 \right)} \quad \text{..........} \quad (8)$$

$$V_{Th} = 225.33 + j4.1655$$

i.e

$$V_{Th} = 225.3709 \, V. \quad \text{..........} \quad (9)$$

The torque is given by

$$T_{RQ} = \frac{3 \times \left( \frac{V_s^2}{R_s} \right)}{N_s \left[ \left( R_s + \frac{R_s}{s} \right)^2 + \left( X_s + X_r \right)^2 \right]} \quad \text{..........} \quad (10)$$

(5.44)
substituting also, \( T_{Q2} = \)
\[
3 \times \left( \frac{225.371}{s} \right) \times \left( \frac{0.7402}{s} \right)
\]
\[
157.08 \left( \frac{0.7384 + \frac{0.7402}{s}}{s} \right)^2 + (0.9566 + 0.9566)^2
\]
which is reduced to,
\[
T_{Q2} = \left( \frac{718.0360}{s} \right) \left( \frac{0.7384 + \frac{0.7402}{s}}{s} \right)^2 + (0.915084)
\]
From the above equation, the torque – slip/speed, power-slip/speed characteristic curves are obtained as shown in figures (3 and 7). The responses to the power factor and efficiency are also presented in figures (4) and (5) respectively.

### III. THE MACHINE PARAMETERS

Table.1: Induction Machine Parameters Obtained from Calculation

<table>
<thead>
<tr>
<th>10HP Induction Motor Parameters</th>
<th>Calculated Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stator Current ((I_s))</td>
<td>13.4699 A</td>
</tr>
<tr>
<td>Rotor Current ((I_r))</td>
<td>11.6627 A</td>
</tr>
<tr>
<td>Stator Resistance ((R_s))</td>
<td>0.7384 Ω</td>
</tr>
<tr>
<td>Rotor Resistance ((R_r))</td>
<td>0.7402 Ω</td>
</tr>
<tr>
<td>Stator Core Loss Current ((I_c))</td>
<td>0.3393 A</td>
</tr>
<tr>
<td>Magnetizing Current ((I_m))</td>
<td>5.5430 A</td>
</tr>
<tr>
<td>Excitation Current ((I_0))</td>
<td>5.5534 A</td>
</tr>
<tr>
<td>Stator Core Loss Resist. ((R_c = R_m))</td>
<td>680.58 Ω</td>
</tr>
<tr>
<td>Rotor Leakage Inductance ((L_r))</td>
<td>0.003045 H</td>
</tr>
<tr>
<td>Stator Leakage Inductance ((L_s))</td>
<td>0.003045 H</td>
</tr>
<tr>
<td>Magnetizing Reactance ((X_m))</td>
<td>38.9872 Ω</td>
</tr>
<tr>
<td>Slip ((s))</td>
<td>4.0%</td>
</tr>
<tr>
<td>Rotor Frequency ((f_r))</td>
<td>2.0 Hz</td>
</tr>
<tr>
<td>Shaft Load Torque ((T_{sh}))</td>
<td>44.401 Nm</td>
</tr>
</tbody>
</table>

### IV. THE RESPONSE CURVES

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V. DISCUSSION OF THE SIMULATION RESULTS

The starting current for an induction motor is several times the running current and the starting power factor is much lower than the power factor at rated speed. Both of these features tend to cause the supply voltage to dip during start-up and can cause problems for adjacent equipment. The torque-speed/slip characteristic of this induction motor is shown in figures (7 and 8) above along with mechanical load torque. The rated torque is usually slightly smaller than the starting torque so that loads can be started when rated load is applied. The curve has a definite maximum value which can only be supplied for a very brief period since the motor will overheat if it is allowed to stay longer.

In figure (6), the response of current to the slip is plotted. The starting current is several times larger than the rated current since the back emf induced by Faraday’s law grows smaller as the rotor speed increases. Whenever a squirrel-cage induction motor is started, the electrical system experiences a current surge while the mechanical system experiences torque surge. With line voltage applied to the machine, the current can be anywhere from four to ten times the machine’s full load current. The magnitude of the torque (turning force) that the driven equipment will see can be above 200% of the machine’s full load torque [7]. These wastages of power due to losses account for a reduced internal and thermal efficiency of the machine [8, 9]. The efficiency-slip curve in figure (5) rises sharply and directly proportional to the slip until maximum efficiency is reached. Efficiency then drops gradually with increasing value of slip. These current and torque surges can be reduced substantially by reducing the voltage supplied to the machine during starting. In figure (9), it is shown that as the applied voltage is increased, there is a consequential
increase in the torque for a given speed. One of the most noticeable effects of full voltage starting is the dimming or flickering of light during starting.

Figure 9. Torque-Speed for varying input voltage for 10HP induction machine

VI. CONCLUSION

The performance of this 10hp induction machine has been investigated. The results obtained from simulation show a good response. We have also seen that a design giving a reduction in supply voltage during starting will favour reduction in torque and current damaging effect. The internal and thermal efficiency of the machine is promoted when unnecessary unused power is saved instead of being wasted as heat.

REFERENCES