iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 9 **Issue:** VII **Month of publication:** July 2021

DOI: https://doi.org/10.22214/ijraset.2021.37178

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue VII July 2021- Available at www.ijraset.com

Comparison of Analytical and Software Based Design of Energy Efficient Induction Motor

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Abstract: ***Energy Efficient Induction motor is playing a vital role in current scenario. Due to rising electrical energy demand, increased awareness of global warming, and rising fossil fuel prices, energy efficiency has become increasingly important. Apart from adding capacity, the only practical approach to deal with this situation is to make optimal use of the available energy, which may be done by using energy efficient Motors. The main objective of this paper is to calculate and Compare the Analytical and Electromagnetic Software based design for a 5HP Energy Efficient Motor.***
Keywords: Energy Efficient Motors, Analytical Method, Design, Induction Motor

I. INTRODUCTION

The most common motors found in industry are three-phase induction motors. They have been widely employed in industry in almost all applications because to their simple, durable, and easy to maintain structure. These engines are known as the industry's workhorses. Induction motors are frequently employed in industrial and domestic appliances [1]. In recent decades, both producers and end-users have become increasingly concerned about the energy efficiency of electric motors. New approaches to improve the efficiency of three-phase induction motors have been developed, and other technological solutions are emerging that could lead to even higher efficiency levels. Even though energy saving has been the most important factor in the design of general-purpose industrial motors, this was not done at the price of durability or overall motor performance. Some people believe that the drive for more efficiency would reduce motor life, and that the higher flux densities may cause application issues with the starting current [2]. The ever-increasing interest in high-efficiency motors can be attributed to two key factors nowadays. Electric motors are a large consumer of electricity. The first is the necessity of addressing ever-increasing energy demand by significantly reducing energy use in order to reduce Carbon dioxide emissions. The second benefit is the cost savings that come with using high-efficiency motors [3]. Over the life of the motor, a small increase in efficiency can save a lot of energy and money. Because Energy Efficient Motors have been demonstrated to be a durable and reliable technology [4].

II. BACKGROUND

There is a clear link between motor life and the challenges that it faces. The desired motor performance and lifespan will usually be attained as long as these stresses are suitably accommodated and controlled within stated design and operation limits [5]. The first significant lines of energy efficient motors were produced in the mid-1970s for the designated product range, with projected penetration of less than 20% of the entire population purchased during this period prior to the Energy Act of 1992.

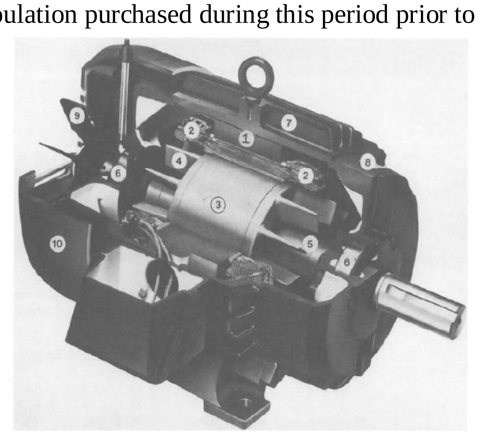

Fig. 1.Cross-sectional view of Electric Energy Efficient Motor : 1-Stator laminated steel; 2-stator windings; 3-rotor; 4-rotor fan blades; 5-shaft; 6-bearings; 7-frame; 8-brackets; 9- external fan; 10-fan cover. (Source: Reliance Electric Company.)

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III. ANALYTICAL DESIGN

A. Input KVA and output co-efficient

Output co-efficient

$$C_0 = 1.1 * k_w * B_{ac} * AC * 10^{-3}$$

KVA input $Q = C_0 D * 2 * L * ns$

(Where, k_w = Winding factor = $k_c * k_d$, B_{av} = Specific magnetic loading, ac = Specific electric loading) D = Diameter of core, L = Length of core, s = speed in r.p.s. (rotation per second) =N/60.

D and L $$D^2 * L = \frac{KVA}{C_0 * ns} \qquad L = \pi * \frac{D}{p}$$

Flux per pole $$\emptyset_m = B_{av}\frac{\pi DL}{p}$$

Turns per phase $$T_s = \frac{E_s}{4.44 K_{ws} * f * \emptyset_m}$$

Where, K_{ws} = 0.955 (assumed).

Voltage per phase $E_s = 4.44\, K_{ws} * f * \phi_m * T_s$

Stator current per phase $$I_s = \frac{Q}{3E_{ph}}$$

Length of Airgap $L_g = 0.2 + 2\sqrt{DL}$ mm

1) Iron Losses

Stator core losses: $P_{s(h+e)}$

Rotor core losses: $P_{r(h+e)}$

2) Copper Looses

The losses in the stator are $P_{SCL} = 3 * I^2_{sp} * R_{sp}$

The losses in the rotor are $P_{rc} = 3 * I^2_{2} * R_2$

Friction and Windage losses: P_{fw}

Stray load losses: P_{misc}

3) Total Losses

$$P_{loss} = P_{s(h+e)} + P_{r(h+e)} + P_{fw} + P_{misc}$$

4) Efficiency (η)

$$\eta = \frac{P_o}{P_o + P_{loss}}$$

$$\eta = \frac{Power\ Out}{Power\ In} = \frac{P_{out}}{P_{in}}$$

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TABLE I

The Performance Parameters of an 5HP Energy Efficient Induction Motor By using Analytical Procedure

Parameters	Outputs Obtained by Analytical Procedure
Frequency (Hz)	50
No. of Poles	4
Speed (RPM)	1500
Power Factor	0.8
Turns / phase	228
Line Current(A)	7.269
Iron Losses (W)	58.96
Copper Losses(W)	264.11
Friction and Windage Losses (W)	28.125
Stray load losses (W)	91.2
Efficiency (%)	89.41

IV. INDUCTION MOTOR DESIGN USING ELECTROMAGNETIC SOFTWARE

Geometrical data are used to describe the motor. The first piece of information presented is the machine's kind, which is a three-phase induction motor.

Stator Parameters	Value	Rotor Parameters	Value
Slot Number	36	Rotor Bars	26
Stator Lam Dia	220	Pole Number	4
Stator Bore	109	Bar Opening [T]	2.5
Tooth Width	4.8	Bar Opening Depth [T]	1
Slot Depth	40	Bar Tip Angle [T]	20
Slot Corner Radius	0	Rotor Tooth Width [T]	5.5
Tooth Tip Depth	1	Bar Depth [T]	24
Slot Opening	3	Bar Corner Radius [T]	0
Tooth Tip Angle	60	Airgap	0.4
Sleeve Thickness	0	Banding Thickness	0
		Shaft Dia	25
		Shaft Hole Diameter	0

Fig 2 Geometical Radial Corss-Section Input data.

Radial Dimensions	Value	Axial Dimensions	Value
Stator Lam Dia	220	Motor Length	225
Stator Bore	109	Stator Lam Length	110
Airgap	0.4	Rotor Lam Length	110

Fig, 3. Axial Cross-Section Input data

The stator dimensions are represented by the first two columns of the radial cross-section input data and the Rotor dimensions are represented in last two columns as shown in Fig.2.

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Drive | E-Magnetics | Equivalent Circuit | Flux Densities | Losses | Wind

Variable	Value	Units
Stator Copper Losses (Analytic on load)	127.8	Watts
Rotor Copper Losses (Analytic on load)	121.6	Watts
Stray Load Losses (Analytic on load)	92.23	Watts
Stator iron Loss [total] (Analytic on load)	63.94	Watts
Rotor iron Loss [total] (Analytic on load)	0.8705	Watts
Windage Loss (adjusted)	4.108	Watts
Friction Loss (adjusted)	23.23	Watts

Total Losses (Analytic on load)	433.8	Watts

Fig. 4. Losses of 5Hp EEIM in Software.

The Losses obtained by the Software are presented the in Fig. 4. The total Copper losses are 249.4 watts, total Iron Losses present are 64.81watts, Friction and Windage Losses are 27.338 watts and Stary load loasses are 92.23 watts.

TABLE IIIII
The Performance Parameters of an 5HP Energy Efficient Induction Motor By using Software

Parameters	Electromagnetic Software Outputs
Frequency (Hz)	50
No. of Poles	4
Speed (RPM)	1500
Power Factor	0.81
Turns / phase	228
Line Current(A)	7.1495
Iron Losses (W)	65.56
Copper Losses(W)	249.3
Friction and Windage Losses (W)	27.446
Stray load losses (W)	92.51
Efficiency (%)	89.60

V. CONCLUSIONS

Table IVVVI
The Performance Parameters of an 5hp EEIM Outputs are Compared Between Analytical Procedure and Electromagnetic Software

Parameters	Outputs	
	Analytical Procedure	Electromagnetic Software
Frequency (Hz)	50	50
No. of Poles	4	4
Speed (RPM)	1500	1500
Power Factor	0.8	0.81
Turns / phase	228	228
Line Current(A)	7.269	7.1495
Iron Losses (W)	58.96	65.56
Copper Losses(W)	264.11	249.3
Friction and Windage Losses (W)	28.125	27.446
Stray load losses (W)	91.2	92.51
Efficiency (%)	89.41	89.60

The Analytical method and Electromagnetic Software outputs are compared in the Table III above. Considering main performance parameters like power factor, line currents(A), Iron and copper losses(W), friction and windage losses (W), stray load losses(W), and efficiency(%). It clearly shows that the Design based on Electromagnetic Software gives the better Efficiency then the Analytical procedure, because the software will consider the Saturations points of the material. Where as in Analytical procedure it is difficult to consider and Calculate the Saturation points. Thus, the Iron Losses are higher in Electromagnetic Software then Analytical Procedure but other parameters are better by designing a EEIM by Using Electromagnetic Software with an Efficiency of 89.6%.

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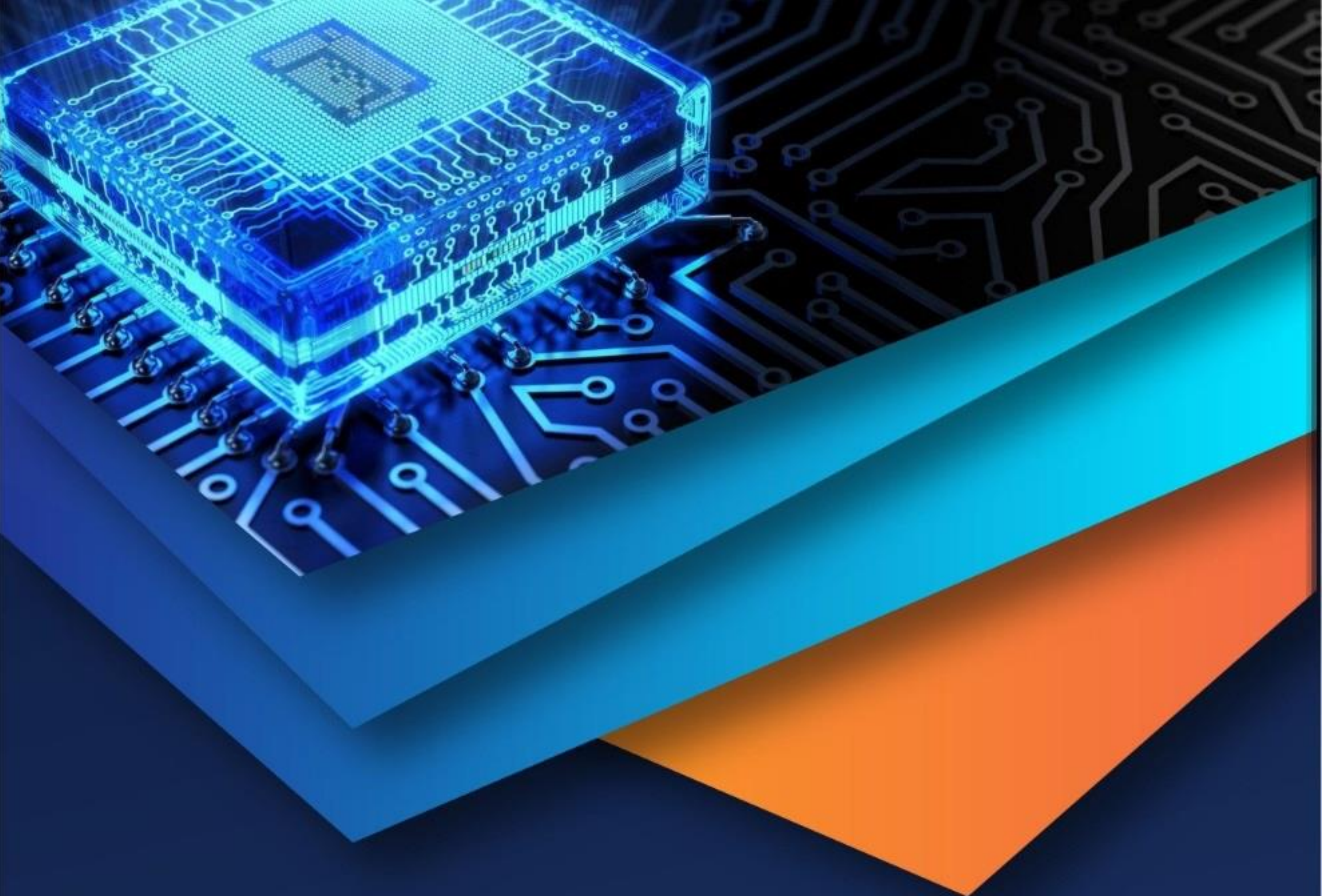

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