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Impact of Harmonics on Performance of Energy efficient and standard Induction Motor in MATLAB Environment

Anubhav Kumar
Research Scholar M.Tech.
Takshshila Institute of Engineering & Technology
Jabalpur (M.P.), [INDIA]
Email:anubhavkumar9@gmail.com

Pramod Dubey
Assistant Professor
Takshshila Institute of Engineering & Technology
Jabalpur (M.P.), [INDIA]
Email:PramodDubey@takshshila.org

Abstract

This study investigates the impact of harmonics on the performance, efficiency, and also the economics of motors (EEMs) and commonplace motors (STMs). During this analysis, the electrical phenomenon electrical phenomenon model that includes the electrical phenomenon within the rotor bars is employed to check the motor's behavior beneath harmonics. The characteristic behavior of the motors area unit simulated victimization a worm that compares the performance, efficiency, and the social science of these motors and identifies the harmonic level at that these behavior area unit most outstanding. The subsequent motor sizes twenty five, 50HP, 100 HP, 150 HP, 200 HP, 250 HP, and three hundred horsepower area unit utilized in the execution of this study

Keywords:— *Induction motor, harmonics, Fourier series, Matlab, losses of induction motor.*

I. Introduction

The largest portion of electricity consumed is employed by induction motors. Over of all electrical energy consumption in the India is by electric motors and over 2 third of electricity utilized by business is electrical motor [11]. Raising the potency of electrical motors is of high priority. within the last 20 years, vital effort has been created by makers of electrical motors in the technique of construction of energy efficient motors (EEM). This effort has resulted in improvement in full-load efficiencies of electrical motors. The Energy Policy Act (EPACT) of 1992 that was enforced in 1997 needs that each one general purpose point in time single speed squirrel-cage induction motors factory-made within the North American nation rated from 1 – two hundred horse power (hp) should meet minimum potency levels. Motor potency standards have succeeded in remodeling the motor marketplace, leading to vital energy savings and carbon reductions. As a results of the standards that was enacted as a part of the EPAct-92 [10]. The importance of this investigation is to more explore area wherever energy economical motors are still vulnerable to vital losses once subjected to non- curving supply such as harmonics. It has been established that harmonics considerably impact the operation of normal motors however their impact on energy economical motors has not been totally investigated, additionally the harmonics order at that these losses area unit most vital has not be documented.

II. Standard Motor Efficiency

During the period from 1960 to 1975, electric motors, particularly those in the 1- to 250-hp range, were designed for minimum first cost. The amount of active material, i.e., lamination steel, copper or aluminum or magnet wire, and rotor aluminum, was selected as the minimum levels required meeting the performance requirements of the motor [1]. Efficiency was maintained at levels high enough to meet the temperature rise requirements of the particular motor. As a consequence, depending on the type of enclosure and ventilation system, a wide range in efficiencies exists for standard NEMA design B polyphase motors. Table 1 is an indication of the range of the nominal electric motor efficiencies at rated horsepower. These data are also presented in Fig. 1. The data are based on information published by the major electric motor manufacturers. However, the meaning or interpretation of data published prior to the NEMA adoption of the definition of nominal efficiency is not always clear. In 1977, NEMA recommended a procedure for marking.

Table 1 : Full-Load Efficiencies of NEMA Design B Standard Three-Phase Induction Motors

HP	Nominal Efficiency range	Average Nominal Efficiency
1	68-78	73
1.5	68-80	75
2	72-81	77
3	74-83	80
5	78-85	82
7.5	80-87	84
10	81-88	85
15	83-89	86
20	84-89	87.5
25	85-90	88
30	86-90.5	88.5
40	87-91.5	89.5
50	88-92	90
60	88.5-92	90.5
75	89.4-92.5	91
100	90-93	91.5
125	90.5-93	92
150	91-93.5	92.5
200	91.5-94	93
250	91.594.5	93.5

The three-phase motors with a NEMA nominal efficiency. This efficiency represents the average efficiency for a large population of motors of the same design [6]. In addition, a minimum efficiency was established for each level of nominal efficiency. The minimum efficiency is the lowest level of efficiency to be expected when a motor is marked with the nominal efficiency in accordance with the NEMA standard. This method of identifying the motor efficiency takes into account variations in materials, manufacturing processes, and test results in motor-to-motor efficiency variations for a given motor design. The nominal efficiency represents a value that should be used to compute the energy

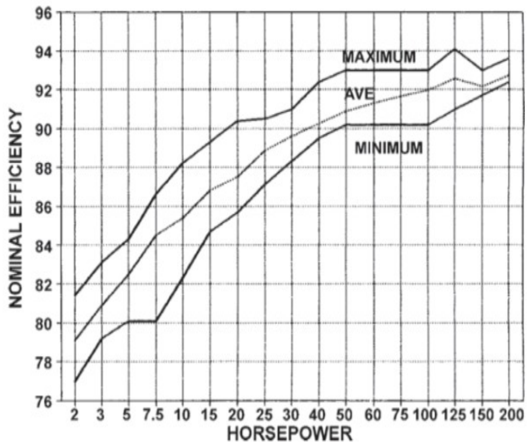

Figure 1: Nominal efficiency range of standard open NEMA design B 1800-rpm polyphase induction motors.

Consumption of a motor or group of motors. Table 2.1 shows a wide range in efficiency for individual motors and, consequently, a range in the electric motor losses and electric power input

Objective

The objective of this research is to study the losses due to harmonics on energy efficient motors and identify at what harmonic level these motor losses are most significant. This study also investigates the losses on standard motors under the same nonlinear load condition. Multiple motor sizes (25hp, 50hp, 100hp, 150hp, 250hp, and 300hp) were used for this study.

The efficiency of the EEM will be evaluated under this application by using the skin effect impedance model. This model accounts for the nonlinear dependence of rotor bar impedance with frequency [6].

Motor Losses

The losses associated with these motors can be categorized into five major types. The first type of loss is the primary I^2R loss which is the copper loss that is due to the stator windings. The secondary I^2R loss is considered the second type of induction motor loss [5]. This loss is due to the rotor bars and end rings of the motor. The third type of induction motor loss is the losses in the iron core of the motor. Friction and windage loss in the induction motor which is caused by the friction in the bearings of the motor and aerodynamic losses associated with the ventilation fan and other rotating parts are considered the fourth type of motor loss. The fifth and most elusive is the stray load loss [7]. The stray load losses arise from variety of sources and are very difficult to identify or measure. At each of the harmonic levels these losses are calculated and are used to calculate the efficiency of the motor. However, since the no load loss provided by the motor vendor can represent the friction, windage and iron core losses of the motor, they are considered constant regardless of the harmonic level. The skin effect impedance model equivalent circuits of a three-phase induction motor are shown in Figure 3.4.

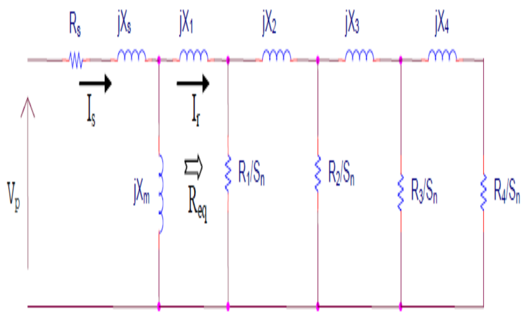

Figure 3.4: The skin effect impedance model

Where R_s and X_s refer to the stator resistance and reactance respectively, X_m is the magnetizing reactance, I_s and I_r are the stator and the rotor current. S_n is the slip of the motor which is dependent on the harmonic. R_{eq} is the equivalent motor impedances looking into the rotor as shown in Figure

Calculating Motor Losses:

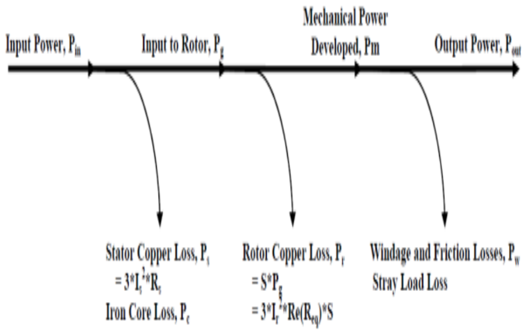

Figure 3.5: Power Flow in an Induction Motor

Input Power

The total electrical power input can be calculated as shown in 3.24

$$P_{in} = \sqrt{3} * V_p * I_s * \cos\theta \quad \text{.........................} (3.24)$$

Where V_p, I_s, and Cos $)^{\theta}$ are the fundamental voltage, stator current and the power factor of the motor respectively.

Stator Loss

The formula to calculate the stator loss of the motor is given by

$$P_s = 3 * I_s^2 * R_s \quad \text{…………..……..} (3.25)$$

Where, R_s is the stator resistance.

Rotor Loss

The power transferred across the air gap, P_g which is also known as the rotor input power is first calculated as shown below. The rotor resistance loss is then calculated based on the slip of that harmonic order as shown

$$P_g = 3 * I_s^2 * R_g \quad \text{…..……………..} (3.26)$$

Where R_g is the real part of the parallel combination of jX_m and R_{eq}

$$P_r = S * P_g \quad \text{……………………..…. (3.27)}$$

The rotor loss can also be calculated using equation 3.28

$$P_r = 3 * I_r^2 * Re(R_{eq}) * S \quad \text{……... (3.28)}$$

Stray Losses

Stray loss cannot be easily calculated. It is actually the sum of several smaller losses that are dependent on the motor operation. For this study, the stray loss is assumed to be 0.5% of the total input power at each harmonic order based on International Electrotechnical Commission, IEC standard. So,

$$P_{strayLoss} = 0.005 * P_{in} \quad \text{……………… (3.29)}$$

3. RESULTS AND DISCUSSION

A thorough investigation of the impact of harmonics on the operation of energy efficient motors and the standard motors was conducted with the aid of computer programs using Matlab software and using the data supplied by the motor manufacturer [15]. The computer program compares the characteristic behavior of these motors (EEMs and STMs) at the fundamental frequency and at different orders of harmonics. The manufacturer supplied data used is given in Appendix A. All values displayed on the graph are in per unit, (p.u), and percentages.

Graphical reports

The graphs shown in Figures 1 – 6, obtained from the computer analysis for this of the 250hp motors [8]. Each of the graphs show the overall analysis of this study based on their corresponding rating. The graphs include, the total cumulative loss of both the STM and EEM in per unit, the associated secondary ohmics loss (rotor loss) in per unit, the percent increase in rotor loss in percentage, the associated primary ohmics loss (stator loss) in per unit, the percent increase in stator loss in percentage, the efficiencies of EEM and STM in percentage, percentage decrease in efficiencies for each motor, the yearly savings (Rs), percent increase in yearly savings in percentage and the payback period in year(s).

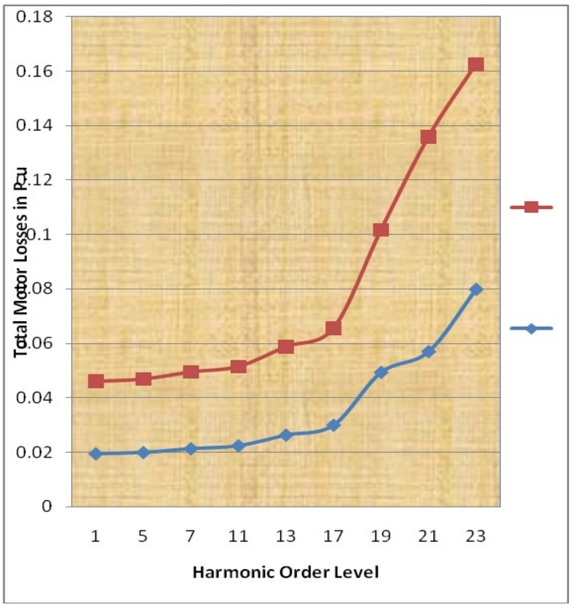

Figure.1: Cumulative Total Losses for 25HP Motors

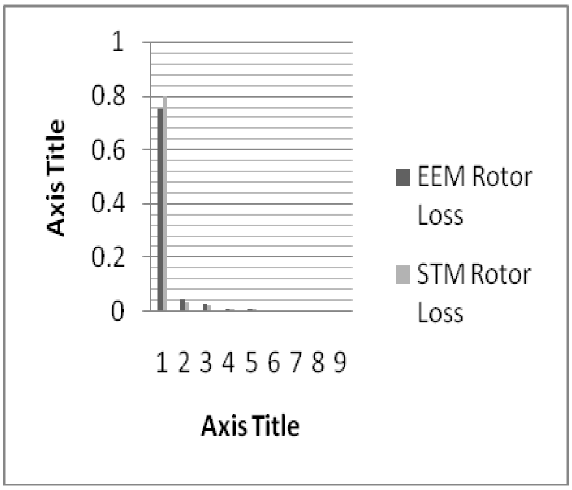

Figure 2: Rotor Losses for 25HP Motors vs. Harmonic Order

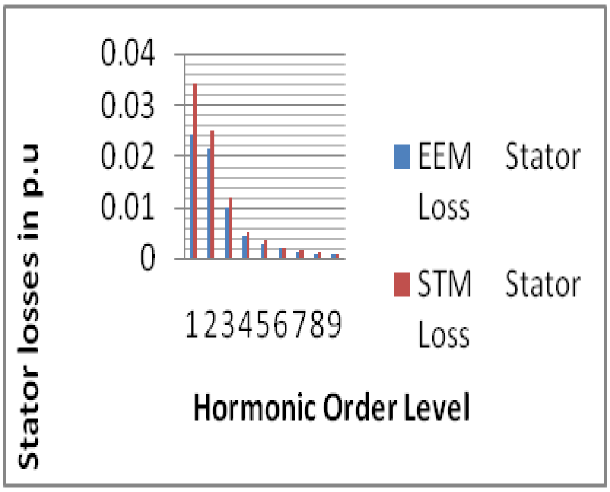

Figure 3: Stator Losses for 25 HP Motors vs. Harmonic Order

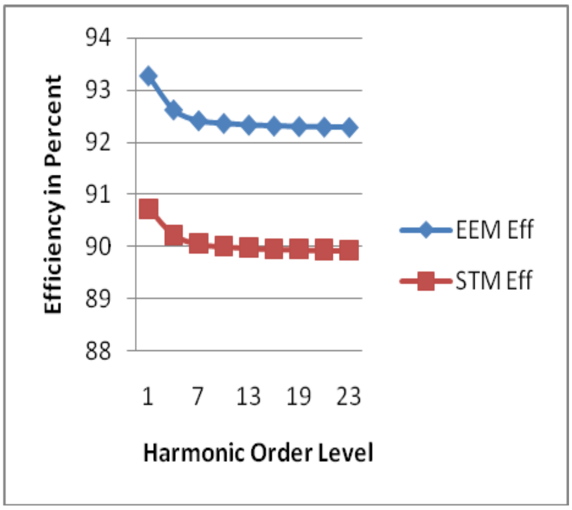

Figure 4: Efficiencies for 25 HP Motors vs. Harmonic Order

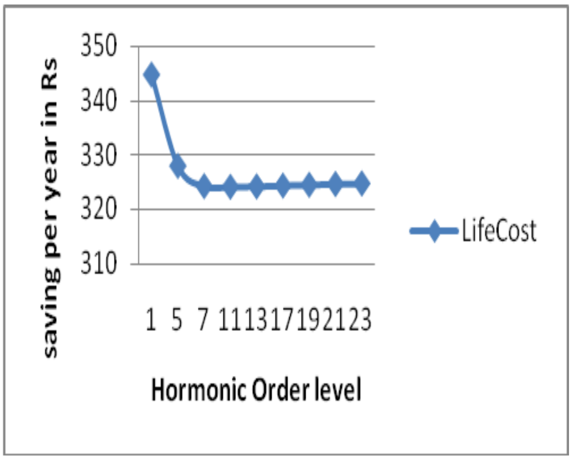

Figure 5: Yearly Savings for 25 HP EEM over STM vs.

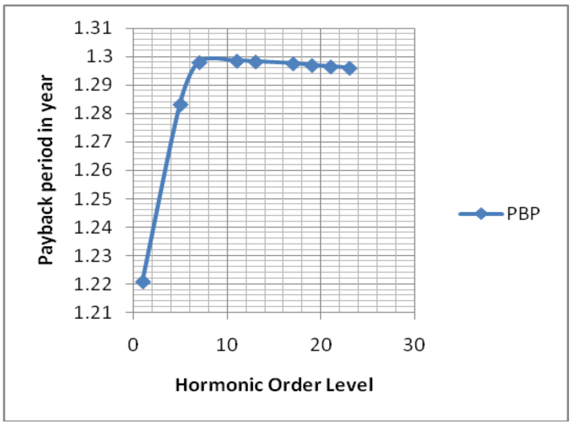

Figure 6: Payback Time for 25 HP Motors vs. Harmonic

V. CONCLUSION

In this study, the behavior of the energy efficient and the standard motors when subjected to harmonic conditions were investigated and compared. The skin effect impedance model was used in the analysis of this study. Computer program was used to simulate the characteristic of the motors. The losses due to harmonic were calculated and documented; the efficiencies of the motors and its economic impact on these motors were well understood. In addition, the harmonic orders that contributed the most loss to the motors' total losses were identified. The methodology adopted in this study supported the overall objective of this research. It was determined and verified that energy efficient motor is more cost efficient even under harmonic load.

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