Energy Saving in Steel Industry by Replacing Standard Induction Motors With Energy Efficient Motors

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***Abstract*— Now, a day's energy consumption in India in various plants is a great issue. The standard induction motors operating in plant have poor efficiency and consume large amount of energy. To save energy consumption in plant, the use of energy efficient motors is preferable over standard induction motor due to their better design, material and manufacturing. The advantages of energy efficient motors over standard induction motors in terms of electrical energy saving and reduction in load demand in a factory are thoroughly evaluated. The plant under study has 94 motors of various ratings. The main objective of paper is to encourage the use of energy efficient motors in a plant instead of standard induction motors. For this purpose, comparison of standard motors with energy efficient motors based on current, power factor, efficiency, motor input power(kW), apparent power (kVA), demand cost per kVA and energy cost is made accordingly the running hours in a year. The payback period in years is also calculated. In the end, it is found that the use of energy efficient motors is better and results in reduction of the overall plant motor load (kW demand) within the organization.**

Keywords*— *Standard induction motor, energy efficient motor, running cost, energy conservation

I. Introduction

In India, nearly 70% of the produced electric energy is consumed by 3 phase induction motors in various industries. Due to limited stock of energy sources, the cost of electric energy is increasing. Hence running cost of these induction motors is a real concern. In early period, the design of standard 3 phase induction motor was based on the initial cost of motor rather than energy it consumes. The material used in standard induction motor is lower cost annealed steel and lower amount of copper in winding. Hence these motors have poor efficiency, poor power factor and greater losses. Due to lower efficiency, use of standard motors in plant is very expensive. Therefore new motors are designed by using higher quality materials, thinner steel laminations and higher amount of copper in winding. These motors are called high efficiency motor or energy efficient motor. Energy efficient motors have high efficiency (2-3% higher than standard motors) which results in less energy consumption. Hence use of efficient motors reduces the running cost of plant. Lot of work has been carried out in improvement of design of energy efficient motors. In 1984 Stuckey G [11] has introduced the change in design of motor to increase its efficiency by improving slot shape. Buchanan et al. in 1989 [3] have described investigation of energy management system in large commercial building and result indicated that a well tuned energy management system can result in 10 – 40% reduction in bill demand. Werner et al. [5] have introduced the use of various steels in motor. The performance of lower core loss steel is economically justified when operating cost of motors are considered.

In 1995, Pillay and Fendly [9] have made a survey of electric motors in refinery and chemical plant. Energy saving in chemical plant by using energy efficient motors has been also discussed. In [2], Bonnet has given a review on various industrial motor available. In [6], Hamer et al. produced efficient test result and loaded speed measurement for standard and premium efficiency motor with a conclusion that high efficiency motor should be operated at 5-10% above rated voltage for best system efficiency.

In 1999, Mehmet [8] has made a full design comparison of 200 hp energy efficient motor and standard motor with reference to Bahrain market which results in energy conservation. In [4], Barney has discussed that availability of high power factor motors can result in electric cost saving. In [7], Slack has made a comparison of cost effectiveness of installing capacitor on individual motors with the cost effectiveness of installing high efficiency high power factor motors. Boglietti et al. in [1] have made comparisons between copper squirrel cage motors with aluminium cage induction motors based on torque, efficiency, starting torque and starting current. In [10], Singh et al. have compare performance of standard motor with energy efficient motor based on number of parameters viz. voltage, current, power and power factor.

In this paper, load demand of steel industry is reduced and it further leads to save energy by using energy efficient motors. Comparisons of standard motors with energy efficient motors have been made based on efficiency, power factor, motor input power (kW), kVA, demand cost per kVA and energy consumed. Payback period is also calculated which is less than 2 year.

After this brief introduction, the paper is structured as follows: In section 2, standard induction motor and energy efficient motor are briefly discussed. Section 3 is dedicated to energy efficiency motor. In section 4, analysis of energy efficient motors with standard motors have been carried out. Finally paper is concluded in section 5.

II. STANDARD INDUCTION MOTOR

Induction motors are used to convert electrical energy into mechanical energy. Mostly 3 phase squirrel cage type induction motors are used in industry because they are rugged, reliable and economical. Induction motor is basically made up of two parts: A stator and a rotor. Field winding is placed in stationary part of motor and copper bars are placed in rotor. Generally rotor is of two types

1) Squirrel cage rotor

2) Phase wound rotor

A. Squirrel Cage rotor

Squirrel cage rotor is comprised of a number of thin bars, usually aluminium, mounted in a laminated cylinder. The bars are arranged horizontally and almost parallel to the rotor shaft. At the ends of the rotor, the bars are connected together with a shorting ring.

B. Slip Ring rotor

Slip ring rotor motor is a type of induction motor in which slip rings are connected with rotor winding. Starting torque of slip ring motor can be increased by inserting external resistance in rotor circuit.

C. Synchronous Speed

Synchronous speed is the speed of motor with which the stator magnetic field rotates. The speed of standard induction motor can be calculated by using following relation

$$N_S = \frac{120 \times f}{P} \qquad (2.1)$$

The speed (Ns) of induction motor depends on the frequency (f) and numbers of poles (p) for which motor is wound.

D. Power factor

It is the angle between phase voltage and phase current. Alternatively, it may be defined as ratio of active power (kW) to apparent power (kVA). The power factor of plant is low because of inductive load, which is mainly due to induction motors. So low power factor problem leads to power factor penalty charge and increased running cost. To minimize the low power factor and low efficiency problems, various manufacturers have made high efficiency motors by changing the design of standard motors which are called energy efficient motors.

III. ENERGY EFFICIENT MOTORS REPLACING OVER STANDARD MOTORS

Energy efficient motors are high efficiency motors with improved design, high quality materials and increased reliability. High efficiency is obtained by using thicker conductor, special fan design, longer core length and uniform air gap between stator and rotor. Efficiency of energy efficient motor is 2-3% higher as compared to standard induction motor as shown in Fig. 3.1.

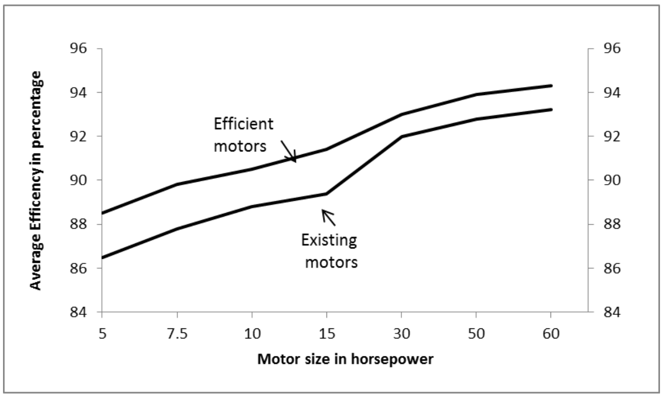

Figure 3.1

Efficiency comparison of standard v/s efficient motor

Improvement in motor design, better materials and manufacturing improvement reduce motor losses hence making electric motor more efficient. The increased efficiency of Energy efficient motor [EEM] leads to reduce running cost of plant, load demand, kVA demand. The price of energy efficient motors is more as compared to standard induction motor. The payback period can vary substantially with different power costs and hours per year of running time. The years to payback the premium cost for the energy efficient motor can be calculated by using equation 3.1

$$\text{Payback period in years} = \frac{\textit{premium cost}}{\textit{annual saving}} \qquad (3.1)$$

IV. RESULTS AND ANALYSIS

In this case study, data of 94 standard induction motors operating in plant have been collected. The data included motor rating, speed, efficiency, current and power factor. Table 4.1 shows the data of operating motors in plant.

Table 4.1: Actual data of standard motors operating in plant under study

S.NO	Rating of motors (hp)	Current (Amp.)	SPEED (RPM)	Power factor	Efficiency (%)	Input Power (kW)	No of motors (n)
1	7.5hp 2 pole	10.18	2890	0.88	87.0	6.43	5
2	20 hp 2 pole	26.2	2940	0.88	90.5	16.48	12
3	5 hp 4 pole	8.0	1430	0.84	86.5	4.31	6
4	7.5hp 4 pole	10.25	1440	0.86	87.8	6.37	16
5	10 hp 4pole	13.47	1440	0.88	88.8	8.40	15
6	15 hp 4pole	19.45	1440	0.88	89.4	12.51	8
7	30 hp 4pole	38.2	1460	0.87	92.0	24.32	11
8	50 hp 4 pole	63.8	1475	0.87	92.8	40.19	8
9	60 hp 4 pole	76.3	1475	0.88	93.2	48.02	6
10	30 hp 6 pole	39.5	975	0.84	91.1	24.56	7

The operating motors operating already in plant are old and have poor efficiency. The motors are working for 18 hours daily. Due to low power factor and less efficiency, standard induction motors consume more energy. The total motor load of plant is 1633 kW. Due to low power factor of already operating standard induction motors, energy suppliers may charge according to kVA demand and low power factor also leads to power factor penalty charges. For energy conservation and to reduce the load demand of plant, a proposal has been made to replace standard motors with energy efficient motors. Table 4.2 shows data sheet of EEM

Table 4.2: Data sheet of energy efficient motors replacing over standard motors

Motor Rating (hp)	Speed (RPM)	Current (A)	Efficiency (%)	Power factor
7.5hp 2 pole	2900	9.5	89.3%	0.90
20 hp 2 pole	2930	26	92.1%	0.88
5 hp 4 pole	1450	7.1	88.5%	0.84
7.5hp 4 pole	1450	10.4	89.8%	0.86
10 hp 4pole	1450	13.7	90.5%	0.88
15 hp 4pole	1460	20	91.4%	0.89
30 hp 4pole	1465	39	93%	0.89
50 hp 4 pole	1475	64	93.9%	0.88
60 hp 4 pole	1475	77	94.3%	0.89
30 hp 6 pole	975	39.5	92.4%	0.84

From the data sheets of energy efficient motors and standard motors, analysis of 7.5 hp 2 pole motor is presented below. Table 4.3 shows the input data of 7.5 hp 2pole standard and efficient motors for calculations.

Table 4.3 Analysis of 7.5 hp 2 pole motor

Voltage	415 V
Current	10.11A
Frequency	50 Hz
Efficiency of SM	87.0%
Power factor of SM	0.88
Demand charge per kVA per year	Rs.200
Life of motor	18 yr
Energy rate per kWh	Rs.6.26/-
Efficiency of EEM	89.3%
Power factor of EEM	0.90

V. Calculations

Motor input power (kW) of SM = (hp ×0.746) / efficiency = (7.5×0.746) /0.87 = 6.43 kW

Motor input power (kW) of EEM = (7.5×0.746) /0.893 = 6.26 kW

kVA for standard motor = kW / pf ×eff = (7.5 × 0.746) / (0.88× 0.87) = 7.31 kVA

kVA of standard motor for 18 years = 7.31 ×18 = 131.58 kVA

kVA for energy efficient motor = (7.5 ×0.746) / (0.90 × 0.893) = 6.96 kVA

kVA of energy efficient motor for 18 years = 6.96 ×18 = 125.28 kVA

Demand cost @Rs 200 per kVA of standard motor per year = 7.31 ×200= Rs.1462/-

Demand cost @Rs 200 per kVA of energy efficient motor per year = 6.96 ×200= Rs.1392/-

Demand cost saving per year = 1462 – 1392 = Rs.70/-

Demand cost saving for 18 year =Rs.70 ×18 = Rs.1260/-

Annual cost saving S = 0.746×hp×P×H× (100/E2 – 100/E1)

= 0.746×7.5×6.26×6480× (100/87.0 – 100/89.3) = Rs.6809

Annual cost saving for 18 years = Rs.6809 × 18 =Rs.122562

Total annual saving = Rs.6809 + Rs.70 = Rs.6879

Total annual saving for 18 years = Rs 6879 × 18 = Rs.123822

Payback period in years = Premium cost / Annual saving

= (38430 – 33180) / 6879 = 0.76 year

Analysis of remaining efficient motors replacing over standard motor of same rating can be done by using above method. After complete analysis of energy efficient motors with standard motor operating in plant, the result calculated are shown in table below. Table 4.4 shows the total energy saving of plant when using efficient motors over standard motors and payback period.

Table 4.4: Annual saving and payback analysis of energy efficient motors in plant

Motor Rating (hp)	Input power (kW)	Annual saving of each motor (Rs)	No of motors (n)	Total Annual saving (Rs)	Payback period of each motor (years)
7.5hp 2 pole	6.26	6879	5	34395	0.76
20 hp 2 pole	16.19	11565	12	138780	0.92
5 hp 4 pole	4.21	4109	6	24654	0.82
7.5hp 4 pole	6.23	5708	16	91328	0.84
10 hp 4pole	8.24	6695	15	100425	0.83
15 hp 4pole	12.24	10988	8	87904	0.81
30 hp 4pole	24.03	10176	11	111936	1.11
50 hp 4 pole	39.72	19882	8	159056	0.95
60 hp 4 pole	47.46	22036	6	132216	1.03
30 hp 6 pole	24.22	13700	7	95900	0.99

It can be seen form Table 4.4 total annual saving of plant is Rs 976604 by replacing standard motors with energy efficient motors. After complete analysis the study reveals that by replacing standard motors with energy efficient motors the total motor load comes to 1608 kW as compared to 1633 kW as of previous arrangement. As the initial cost of EEM is high but it leads to large energy saving. Investment on efficient motor is economical as the payback period calculated of each motor is less than 2 years.

VI. Conclusion And Future Scope

In this paper, proposal of replacing standard motors with energy efficient motors in steel industry has been made and analysis has been carried out. As per observations, use of EEM reduces the total motor load (kW) and reduce the running cost of plant, which further leads to large amount of energy saving. Analysis of energy efficient motors with modern AC drives for large energy saving is next on our agenda.

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