Application of Energy Efficient Motor in Malaysian Industries

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Abstract: Electric motors are used extensively in every sector of the economy. They perform a wide range of duties throughout the industrial, commercial, residential and agricultural sectors. Motor systems are the largest industrial loads, on average accounting for more than 70 percent of all electricity consumption. Energy consumption of electric motor systems is an important economic and environmental issue. More than half the electricity generated in Malaysia is consumed by electric motor driven system applications. Therefore, industries can save considerable amounts of money on their electricity bills, if they employ motors of higher efficiency, and improve the energy efficiency of the systems driven by these motors.

This paper presents the test procedures to determine the motor efficiency. The case study on the efficiency and improvement in energy usage by retrofitting the motors with high efficiency motors will also be presented. This paper also shows the comparison in performance and cost benefits between standard motor and energy efficient motor using simple payback analysis.

I. INTRODUCTION

Industrial sectors are the biggest consumer in the electric power generated in Malaysia for about 51.9% of the total electricity consumption, i.e. 27211.17 GWh [1]. Since the usage of energy is the most in electric motors, several measures should be taken to reduce the consumption of energy. It is important to introduce energy efficient motor in the industrial sectors. By introducing this motor which have different characteristic from a standard motor, less energy is required to produce the same output torque. Unfortunately energy efficient motor is not widely use in Malaysia. Manufacturer should realize the advantages of energy efficient motors for the purpose of energy savings. The usage of energy efficient motor can reduce financial cost of industrial sector such as the cost of motor maintenance and cost of buying a new motor because it has long life span [2]. Therefore, energy efficient motors can save a substantial

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amount of money in the long run. Using energy efficient motor that have slightly higher efficiency than standard motor can also reduce electricity bill. Efficient use of electricity could reduce the number and type of power plant which have to be built to meet electricity demand.

The paper is organised into the following sections: Section II describes the motor efficiency and losses. Section III describes the test procedures. Section IV presents the results of measured and computed data from the experiment and survey and Section V presents the conclusions.

II. MOTOR EFFICIENCY AND LOSSES

A. Efficiency

Motor efficiency is a measurement of the effectiveness with which a motor converts electrical energy to mechanical energy output to drive a load. It is defined as a ratio of motor power output to source power input. The difference between the power input and power output comprises electrical and mechanical losses. The difference - watts loss - is due to electrical losses plus friction and windage. Even though higher horsepower motors are typically more efficient, their losses are significant and should not be ignored. In fact, higher horsepower motors offer the greatest savings potential for the least analysis effort, since just one motor can save more energy than several smaller motors.

Motor Efficiency = Output/input
= output/(output+losses)
= (HPx746)/(HPx746+losses)

B. Motor Losses

Motor loss refers to the consumption of electrical energy not converted to useful mechanical energy output. Every AC motor has five aspects of power loss, which are the reasons for its inefficiency. Power losses are converted into heat that is dissipated by the motor frame aided by internal or external fans. Combined, these five types of energy loss constitute the total power loss of a motor. Power loss comprises energy converted to heat and dissipated from the motor frame. One of the functions of a cooling mechanism is to alleviate power losses. Motor design alterations that diminish any of these losses contribute to the enhancement of motor efficiency. Reduction of energy losses always improves a motor's efficiency. There are five components of loss in an induction motor, namely :

- Stator losses
- Rotor losses
- Core or iron losses
- Stray load losses
- Friction and windage losses

III. MOTOR EFFICIENCY TESTS

Accurate measurement of motor efficiency is not a simple task. To be able to qualitatively compare the energy conversion performance of different motors, the efficiency of these motors must be determined using the same or comparable methods, e.g. IEEE Standard 112, Method B[3]. Data are gathered from D.C resistance test, no load test and locked rotor test. These data are needed to determine the performance of an induction motor. The performance of an electric motor can be calculated from its equivalent electric circuit. These methods permit one to compute estimates of the efficiency of the motor when it is operating at loads other than those at which measurements were made. The parameters of the motor, in the equivalent circuit, can be found from the D.C resistance test, no load test and locked rotor test.

A. Resistance Measurements

The winding resistances of the motors were measured at room temperature before the tests began in order to ensure that the cold resistance values corresponded to a known uniform winding temperature. The winding temperature during the test was be calculated from the increase in resistance over the room temperature value.

B. No Load Tests

No load tests were conducted on the motors according to IEEE standard 112 in order to determine the core loss and the losses due to friction and windage. The tests were performed by varying the voltage from approximately 125% of rated voltage down to the value, which yielded the lowest value of line current. Values of voltage, current, power, and resistance were recorded for eight values of voltage. After subtracting the stator copper losses the data were extrapolated to zero voltage to determine the friction and windage losses. Core losses were determined by subtracting stator copper losses and friction and windage losses from the total losses at rated voltage.

C. Locked Rotor Tests.

It should be recognized that the testing of induction machines under locked rotor conditions with polyphase power involves high mechanical stresses and high rates of heating. Therefore, it is necessary that :

1. The mechanical means of locking the rotor is of adequate strength to prevent possible injury to personal or damage to equipment.
2. The direction of rotation is established prior to this test.
3. The machine is at approximately ambient temperature before the test is started. The current and torque readings shall be taken as quickly as possible, and, to obtained representative values, the machine temperature should not exceed rated temperature rise plus 40°C. The readings for any point shall be taken within 5 s after the power is applied for motors rated 10 hp and below and within 10 s for all motors above 10 hp rating.

C. Load Tests

The motors were tested at six different load points, spaced nearly equally between 25% to 150% of rated torque. In all cases the motors were loaded to maximum load first, and readings were taken at successively lower values of load. Voltage, current, power, torque, speed and resistance were measured for each load point.

IV. RESULTS AND ANALYSIS

A. Experiment

Tests were performed on three induction motor of 2 hp capacity. The type of test performed were mentioned as in Section III. Fig. 1 and Fig.2 show the graph of efficiency and torque against slip for the respective motors. The maximum efficiency achieved for EEM is at 75% of full load, the starting torque and pull-out torque are 15.3Nm and 26.1Nm respectively. Figure 3, 4 and 5 show the graph of efficiency at 50%, 75% and 100% load against motor rating. These graph show that the EEM achieve a higher efficiency as compared to the SEM.

B. Survey

A survey had been conducted in several industrial areas at Senai, Johor Bahru and one of the factories was considered to determined the energy conservation strategies. The industry has about 226 motors of various sizes. The details of the motor is as shown in Table 1. The operating efficiency of SEM was very low and replacing them with EEM could improve energy savings significantly.

The energy cost saving and payback period is given by the following formula: [4]

S=HPx0.746(1/Es – 1/Ee)HxC (1)

PP=CD/S (2)

Where H = running time per year (hours/year)

C = cost of electrical energy (RM/kWh)

Es = Efficiency of SEM

Ee = Efficiency of EEM

CD = cost difference between two motors

S = energy cost saving per year

The total annual cost saving calculated were RM 49,566.76 and the payback period is given in Table 2.

V. CONCLUSIONS

In Malaysia today, the movement and manufacturing of products use a considerable quantity of electrical energy. More than half the electricity generated is consumed by the electric motor driven system applications. Thus, improvements in the efficiency of the electrical drives would be significant effects in reducing industrial electrical energy requirements. Through improvements in energy efficiency of electric motors, Malaysia can reduce electrical energy consumption significantly and thus enhance international competitiveness.

Unfortunately, the awareness level among the industrial sectors is very low.

The survey shows that most factories are still using the standard motor in their premises even though some of them have knowledge on energy efficient motor. This is due to several factors that delay the installation of the energy efficient motors. Among the factors are as follow:

1. lack of knowledge on energy efficient motor
2. the cost of energy efficient motor is quite high
3. not widely use in Malaysia.
4. follow the old trend because majority factory is using standard efficiency motor
5. no enforcement from government

VI. REFERENCES

[1] Statistics of Electricity Supply in Malaysia 1999; Department of Electricity and Gas Supply Malaysia

[2] J. Howard, Energy Efficient Electric Motor and Their Application, New York: Van Nostrand Reinhold. 1983.

[3] IEEE Standard Test Procedures for Polyphase Induction Motors and Generators, in IEEE Standard 112-1984

[4] J. Andreas, Energy Efficient Electric Motors: Selection and Application, New York: Marcal Dekker.1982

Table 1: Total of motors used in the industry with different rating

Motor Rating (HP)	Quantity
0.25	28
0.5	7
0.75	8
1	24
1.5	2
2	10
3	18
4	82
5.5	2
7.5	4
15	1
20	20
25	6
30	2
40	4
50	2
60	5
75	1
Total	226

Table 2: Total annual cost savings for energy efficient motor at 75% load

Motor Rating (HP)	Energy Saved(kW) At 75% load	Quantity	Energy Cost Savings per unit (RM) at 75% load	Total Annual Savings (RM/year)	Payback Period(year)
0.25	0.034	28	31.02	868.56	2.39
0.5	0.060	7	54.74	383.25	1.75
0.75	0.042	8	38.32	306.56	2.56
1	0.065	24	59.30	1423.20	1.84
1.5	0.061	2	55.66	111.32	1.96
2	0.128	10	116.79	1167.90	1.10
3	0.090	18	82.11	1477.98	1.45
4	0.127	82	115.87	9501.34	2.17
5.5	0.198	2	180.65	361.30	2.38
7.5	0.276	4	251.82	1007.28	2.22
15	0.559	1	510.02	510.02	1.95
20	0.825	20	752.72	15054.40	1.45
25	1.020	6	930.63	5583.78	1.63
30	0.941	2	858.55	1717.10	1.93
40	0.823	4	750.89	3003.56	2.65
50	0.752	2	686.11	1372.22	3.05
60	0.940	5	857.64	4288.20	3.08
75	1.566	1	1428.79	1428.79	2.32
			Total	49566.76	

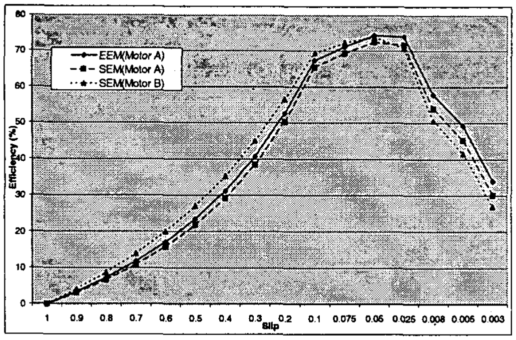

Fig.1 : Graph of Efficiency vs Slip

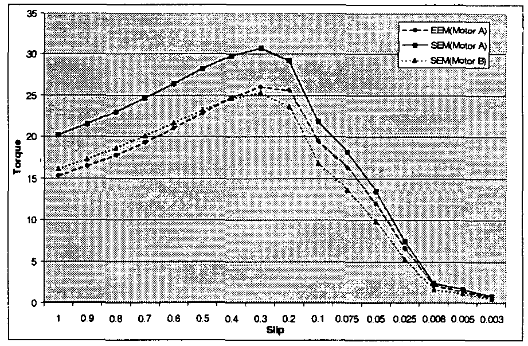

Fig.2: Graph of Torque vs Slip

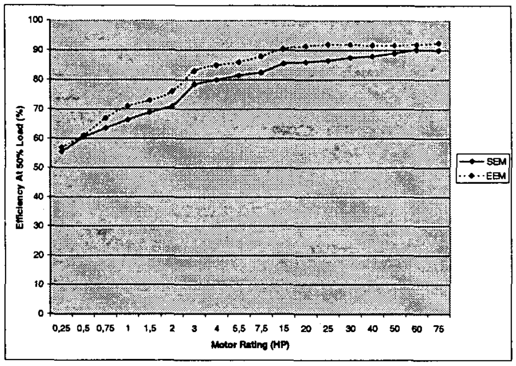

Fig 3: Graph of Efficiency vs motor Rating at 50%

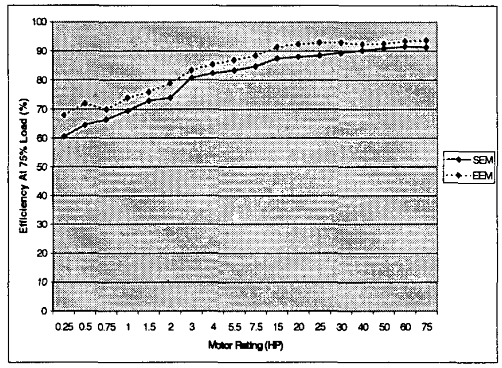

Fig 4 : Graph of Efficiency vs Motor Rating at 75%

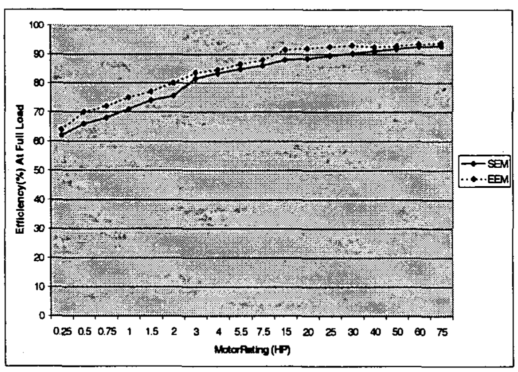

Fig 5 : Graph of Efficiency vs Motor Rating at 100%