Energy Savings, Cost and Environmental Benefit Analysis of Energy Efficient Motors Used for Industrial Drives

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Abstract: In today's power scenario, there is a challenge of meeting the demand of electricity. The gap between the demand and supply of electric energy is widening at the rate of 3 to 4% in India. The demand of electricity in India is increasing at the rate of 8 to 10% every year. As motors are the largest users of electrical energy, even small efficiency improvements can save large energy across the country. To reduce the operating cost and maintain a sustainable environment, one has to reduce the wastage of energy. This paper deals with energy conservation by using energy efficient motors (EEMs) instead of standard efficiency motors. Design improvements in the standard efficiency motors to make them energy efficient are discussed. Due to simple and robust construction, economics and good performance, the 3-ϕ cage IMs is the heart any Industry. Analysis is done for various case studies in which EEM is compared with normal efficiency motors. The energy savings and payback periods by selecting EEM instead of standard efficiency motors are presented.

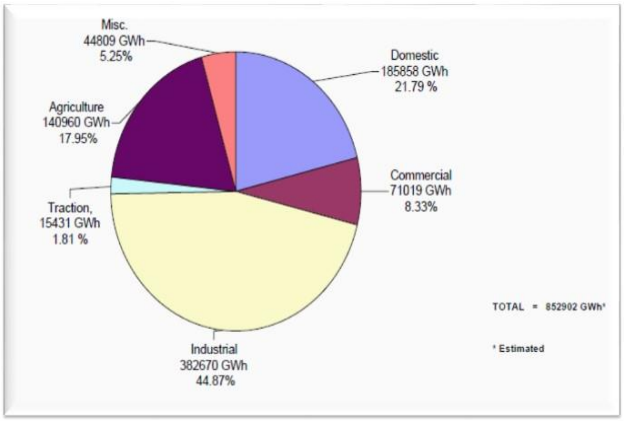
Keywords: EEMs (Energy efficient motors), Induction motor, energy conservation, energy efficiency, energy saving

1. Introduction

Energy is main consideration for the economic development of any country. The demand for electrical energy is continuously increasing due to Industry and growth of the society. The energy cost is also increasing due to limited natural resources and increased cost of raw materials. The competition in the market also increasing hence, only those who are effective and efficient can survive in the market. The operating cost can be reduced by reducing the wastage of energy i.e. by conserving energy.

To reduce the energy consumption, the efficiency of the motor should be as high as possible. Electric motors consume a major part of the electric energy. The advantages of high efficiency motors are: save energy and money, reduce operating cost and reduce greenhouse gas emissions. 70% of all electricity consumed in India is used for driving electric motors. 55% of which is consumed by industrial motors. The Sector wise Electricity consumption in India

Industry 45%
Agriculture 18%
Domestic 22%
Others (Commercial/Traction) 15%



As motors are the largest users of electrical energy, even small efficiency improvements can produce very large savings across the country. Energy conservation measure taken by individual consumers can improve the national economy and benefit the environment on global scale.

2. Energy efficient motor (EEM)

Energy efficiency means using less energy for the same output. Energy efficient equipment of machine uses less energy for the same output and reduces CO2 emissions. The benefits of energy conservation and efficiency to Industry, nation and globe are as follows [6-10]: Industry:

- Reduced energy bill
- Increases profit
- Increases productivity
- Improves quality

Nation:

- Reduce energy imports and
- Improved energy security

Global

- Maintains a sustainable environment
- Reduce CO_2 and other emissions.

An energy efficient motor is one in which the design improvements are incorporated specifically to increase operating efficiency over the motors of standard design. An energy efficient motor produces the same output power (HP) but uses less input power (kW) than the standard efficiency motor. The curves comparing the efficiencies of Standard motors and EEMs are shown in Figure 1 and 2.

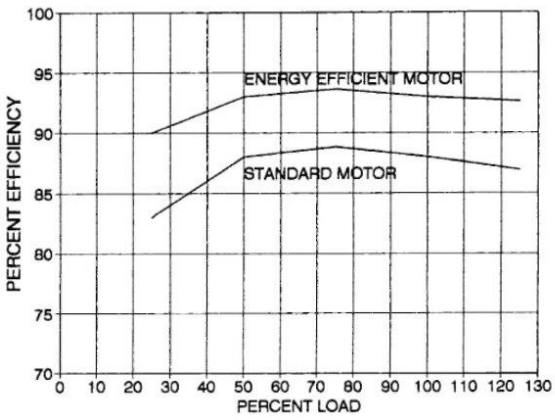


Fig.1. Comparing the efficiencies of Standard motors and EEMs

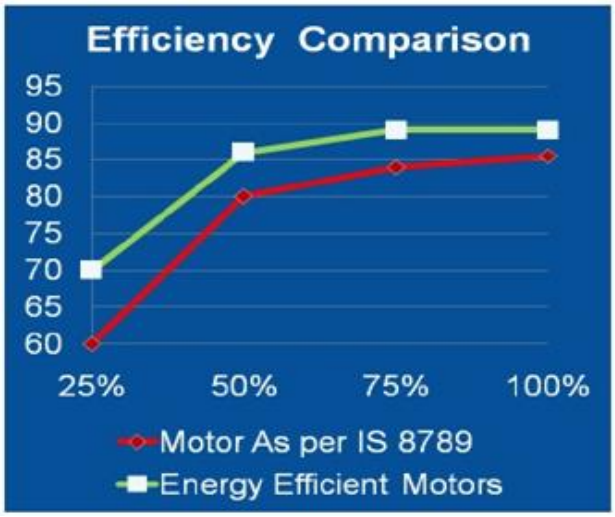


Fig.2. Comparing the efficiencies of Standard normal motors as per IS 8789 and EEMs as per IS 12615

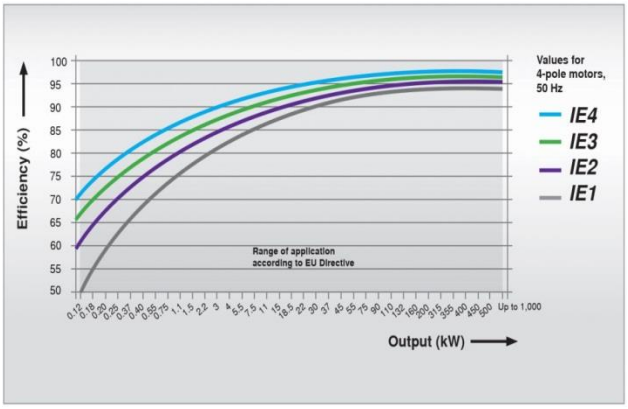


Fig.3. Efficiencies of EEMs for various classes as per IEC/IS

3. Design improvements in the standard induction motor to make them energy efficient

The following design improvements are incorporated in EEMs to reduce the motor losses and hence improve the efficiency [3]:

- Thicker copper wires/conductors to reduce resistance and hence copper losses
- Thinner laminations to reduce eddy current losses
- Use of low loss and high grade silicon steel material for the core of stator and rotor
- A longer core to increase active material and hence reduce iron losses
- Use of Copper bars

- Smaller air gap
- Good bearings, good design fan
- Thinner laminations to reduce eddy current losses
- Use of low loss and high grade silicon steel material for the core of stator and rotor
- A longer core to increase active material and hence reduce iron losses
- Copper bars instead of aluminium bars in the rotor
- Smaller air gap
- Superior bearings and a good design smaller fan

Recommendations when considering an EEMs

- All new installations
- For old rewound motors
- For replacement of oversized and under loaded machines
- For energy conservation
- Purchasing spare motors or replacing failed motors.

4. Benefits when using EEMS over normal or standard motor

- The benefits or advantages using Energy efficient motors are as follows:
- EEM has high efficiency than normal motors. Hence its running cost is low.
- Slip is low; hence its speed is higher than standard motors.
- High power factor than standard motors
- Lower magnetizing or no load current
- EEM has lower operating temperature and noise level
- Less affected by supply voltage fluctuations
- Long life time of windings and bearings due to low operating temperature.
- EEMs are more reliable and require less maintenance than standard motors
- Save energy and money
- Increases the productivity
- Full load efficiencies are higher by 4 to 8% than standard motors
- They have near uniform efficiency from 60% to 100% of full load ensuring energy savings even at part load conditions also.

5. IEC/IS standards for energy efficient motors (EEMS)

- The new IS: 12615 for energy efficient Induction motors (3-phase squirrel cage) is based on the international standard IEC 60034-30, which defines new efficiency classification. It covers single speed, 3-ϕ, 50Hz cage IMs, that have rated voltage ≤1kV, rated output 0.37kW to 375kW, either 2,4 or 6 poles. The efficiency classes defined are [1], [2].
- IE1: Standard
- IE2: High
- IE3: Premium
- IE4: Super premium
- The curves showing the Efficiencies of EEMs for various classes as per IEC/IS are shown in fig.3. The values of nominal efficiency for 4-pole squirrel cage induction motors as per IS 8789[4], IS 12615/IEC 60034-30 are given in the table-I below:

TABLE I
Values of nominal efficiency for 4-pole Squirrel cage Induction motors as per IS 8789, IS 12615/IEC 60034-30

Output rating of Motor, kW 4-pole	Efficiency as per IS 8789	New IS:12615-2011 Energy Efficient Motors		
		IE1	IE2	IE3
3.7	82	82.7	86.3	88.4
7.5	85	86	88.7	90.4
11	85.5	87.6	89.8	91.4
15	86	88.7	90.6	92.1
18.5	87	89.3	91.2	92.6
22	87.5	89.9	91.6	93
37	88.5	91.2	92.7	93.9
75	--	92.7	94	95
110	--	93.3	94.5	95.4
200	--	94	95.1	96

6. Economical evaluation /cost benefit analysis of EEMs

- The energy efficient motors are always expensive due to more laminations or longer core length, high grade low loss silicon steel laminations and more copper used in the machine. Generally, the cost of EEMs is about 15 to 20% more than the standard normal motors [5].
- Relationship to find Energy savings by motor replacement with EEM is determined:

$$kWSavings = kWOutput \times \left[\frac{1}{\eta_{old}} - \frac{1}{\eta_{new}}\right]$$

- Where ηold = efficiency of existing motor and
- ηnew = efficiency of new motor
- Payback Period:
- The payback period for replacing existing standard low efficiency motor by EEM can be calculated by

$$Payback\ Period = \frac{\text{Additional purchase cost of EEM}}{\text{Cost of Energy savings per annum}}$$

- Payback period for replacing existing standard low efficiency motor by EEM can be calculated by

$$Simple\ Payback\ Period = \frac{\text{Price of EEM}}{\text{Annual Cost of Savings}}$$

- Energy Efficient Motor as per IS 12615 gives savings over normal motor.
- The MATLAB Software is used to determine the energy savings and payback period from using a more efficient motor, taking into account price, efficiency, annual hours of use, load factor and electricity costs. Payback period calculation for EEMs is carried out for two different cases as follows:
- Case-I
- A standard or normal 4-pole, 3-phase squirrel cage induction motor having an output of 11kW has efficiency85.5%. A EEM (IE3 Class) with the same output has an efficiency of 91.4%. The additional purchase cost of EEM is Rs. 12250. Table shows the Energy savings per annum and payback period when operating for 5000 hours per year.
- Case-II
- A standard or normal 4-pole, 3-phase squirrel cage induction motor having an output of 3.7kW has efficiency 82%. An EEM (IE3 Class) with the same output has an efficiency of 88.4%. The additional purchase cost of EEM is Rs. 4800. Table shows the Energy savings per annum and payback period when operating for 5000 hours per year.

	Normal Motor as per IS 8789	EEM as per IS12615/IEC, IE3 Class
Purchase price of 11kW/15HP , 4-pole 3-phase squirrel cage Induction motor	63750	76000
Efficiency	85.5%	91.4%
Number of hours of operation	5000	5000
Energy consumption per annum	64327 kWh	60175 kWh
Cost of Energy consumption per annum for 5000 hrs. @ Rs. 5/kWh	321637	300875
Energy Savings per annum	4152 kWh	
Energy savings p.a. Rs.	20760	
Additional Purchase cost	12250	
Payback Period	7 Months	
Simple Payback	3.66 Years	

	Normal Motor as per IS 8789	EEM as per IS12615/IEC, IE3 Class
Purchase price of 3.7kW/5HP, 4-pole 3-Phase Squirrel Cage Induction Motor	24700	29500
Efficiency	82%	88.4%
Number of hours of operation	5000	5000
Energy consumption per annum	22560 kWh	20927 kWh
Cost of Energy consumption per annum for 5000 hrs. @ Rs. 5/kWh	112800	104635
Energy Savings per annum	1633 kWh	
Energy savings p.a. Rs.	8165	
Additional Purchase cost	4800	
Payback Period	7 Months	
Simple Payback	3.612 Years	

7. Environmental benefit

The coal is the primary fuel for electricity generation in India and its usage is continuously increasing to meet the energy demands of the country. The CO2 emission per kWh electricity generation for coal as fuel is approximately 0.9 kg/kWh. Fig.4 shows the CO2 emissions per kWh electricity for different fossil fuels

The annual reduction in CO2 emissions for case-I and case-II are as follows:

Annual reduction in CO2 emissions in case-I: 4152 kWh x0.9 kg/kWh = 3736.8 kg.

Annual reduction in CO2 emissions in case-II: 1633 kWh x0.9 kg/kWh = 1470 kg.

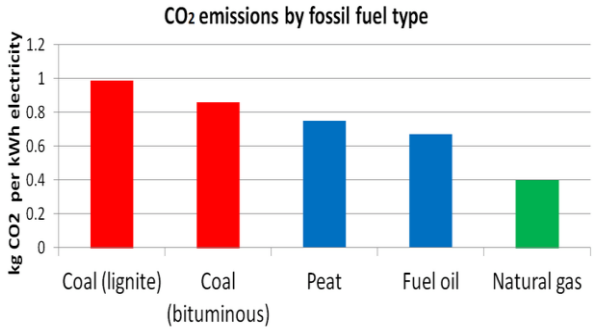


Fig.4 CO2 emissions per kWh electricity for different fossil fuels

By implementing EEMs, CO2 and other greenhouse gas emissions can be reduced and hence maintains a sustainable environment.

8. Conclusion

Energy efficiency should be a major consideration when we purchase or rewind a motor. The annual energy cost of running a motor is usually many times greater than its initial purchase cost. To reduce the operating cost and maintain a sustainable environment, one has to reduce the wastage of energy. Implementing the Energy efficient motors uses less energy for the same output and reduces CO2 and other greenhouse gas emissions.

With case studies/practical cases, it can be seen that energy efficient motors are more efficient than normal motors. Also energy and money is saved and the additional purchase prize is regained with 7 months and total cost of EEM can be regained within 4 years.

By implementing EEMs, the energy and therefore money can be saved and also reduces CO2 and other greenhouse gas emissions.

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