ENERGY EFFICIENT MOTORS AND POWER SAVING

Dr. K. Brahmanandam
E.E.E Department, M.V.S.R.E.C, Hyderabad, India

Abstract
In the Industries most of the motors are standard three phase induction motors. The performance of these motors are effected by voltage unbalance, current unbalance, harmonics, rewinding of motors, temperature rise. In this paper the remedies for these problems are addressed. Standard motors and Energy efficient motors [1,2] are classified as per IEC 34-2.Features of Energy efficient motors [3,4] and labeling as per BIS are covered to save energy and increase efficiency.
Keywords: voltage unbalance, current unbalance, Efficiency, power factor improvement capacitors.

I. Introduction

In india the Electric motors are classified as the standard motors and Energy efficient motors. Both these motors follow the BIS.IS 8789 addresses technical performance of standard motors. Standard motors follow IS 325 to allow(i) 15% tolerance on efficiency for motors upto 50KW rating.(ii)10% tolerance on efficiency for motors above 50 Kw rating. As per Bureau of Indian standards the mounting dimensions of motors follow IS1231 for easy replacement .IS 12615 addresses the efficiency for high efficiency motors.

II.Parametrs effecting performance of electric motors

1.The value of slip calculated using Name plate details is not accurate.The actual measurement of slip at full load condition is accurate.

2.Rewinding of motor results in increase in resistance due to low quality of material and smaller size of winding.

3.Core Losses

Core losses are those found in the stator-rotor magnetic steel and are due to hysterisis effect and eddy current effect during 50 Hz magnetization of the core material. These losses are independent of load and account for 20 – 25 % of the total losses. The hysterisis losses which are a function of flux density, are be reduced by utilizing low loss grade of silicon steel laminations. The reduction of flux density is achieved by suitable increase in the core length of stator and rotor. Eddy current losses are generated by circulating current within the core steel laminations. These are reduced by using thinner laminations.

4. Friction and Windage Losses

Friction and windage losses results from bearing friction, windage and circulating air through the motor and account for 8 – 12 % of total losses. These losses are independent of load.

5. Effect of unbalance in voltage

Voltage unbalance occurs when the voltages of three phases are not equal,unbalance occurs due to unbalanced single phase loads .

Percentage of voltage unbalance = 100 (Vmax – Vavg) / Vavg,

Where Vmax and Vavg are the largest and the average of the three phase voltages, respectively.

Let the three phase supply system has line to line voltages Vab =410 v, Vbc = 417V, Vca = 408 V

Mean = (410+417+408)/3 =411.7v

% voltage unbalance = (417-411.7) x100/411.7 =1.29

6.Effect of unbalance in current

With increase in voltage unbalance , currents also unbalanced. with increase in unbalanced currents operating temperature also increases.And the variation of unbalanced currents with voltage unbalance is as shown in the following table.1.

7.Power Factor Correction

Induction motors are characterized by power factors less than unity, leading to lower overall efficiency (and higher overall operating cost) associated with a plant's electrical system. Capacitors connected in parallel (shunted) with the motor are typically used to improve the power factor. The impacts of PF correction include reduced kVA demand (and hence reduced utility demand charges), reduced copper losses in cables upstream of the capacitor (and hence reduced energy charges), reduced voltage drop in the cables (leading to improved voltage regulation), and an increase in the overall efficiency of the plant electrical system.

It should be noted that PF capacitor improves power factor from the point of installation back to the generating side. It means that, if a PF capacitor is installed at the starter terminals of the motor, it won't improve the operating PF of the motor, but the PF from starter terminals to the power generating side will improve, so the benefits of PF would be only on upstream side.

8.Rise of temperature

Due to voltage unbalance, temperature of winding increases. Then the life of winding insulation reduces.Additional rise of temperature in motor occurs as per the following equation.

$$\text{Additional rise in temperature} = 2 * (\%\text{voltage unbalance}^2)$$

9.Effect of harmonics

In any alternating current network, flow of current depends upon the voltage applied and the impedance (resistance to AC) provided by elements like resistances, reactances of inductive and capacitive nature. As the value of impedance in above devices is constant, they are called linear whereby the voltage and current relation is of linear nature. However in real life situation, various devices like diodes, silicon controlled rectifiers, PWM systems, thyristors, voltage & current chopping saturated core reactors, induction & arc furnaces are also deployed for various requirements and due to their varying impedance characteristic, these NON LINEAR devices cause distortion in voltage and current waveforms which is of increasing concern in recent times. Harmonics occurs as spikes at intervals which are multiples of the mains (supply) frequency and these distort the pure sine wave form of the supply voltage & current. Harmonics are multiples of the fundamental frequency of an electrical power system. If, for example, the fundamental frequency is 50 Hz, then the 5th harmonic is five times that frequency,or 250 Hz. Likewise, the 7th harmonic is seven times the fundamental or 350 Hz, and so on for higher order harmonics. Harmonics can be discussed in terms of current or voltage. A 5th harmonic current is simply a current flowing at 250 Hz on a 50 Hz system. The 5th harmonic current flowing through the system impedance creates a 5th harmonic voltage. Total Harmonic Distortion (THD) expresses the amount of harmonics. The following is the formula for calculating the THD for current:

1. Electrical System

Bureau of Energy Efficiency 19 When harmonic currents flow in a power system, they are known as “poor power quality” or “dirty power”. Other causes of poor power quality include transients such as voltage spikes,surges, sags, and ringing. Because they repeat every cycle, harmonics are regarded as a steady state cause of poor power quality.When expressed as a percentage of fundamental voltage THD is given by,

$$V_{THD\_F} = \frac{100 * \sqrt{\sum_{h=2}^{N} V_{h,rms}^{2}}}{V_{1,rms}}$$

$$I_{THD\_F} = \frac{100 * \sqrt{\sum_{h=2}^{N} I_{h,rms}^{2}}}{I_{1,rms}}$$

where V1 is the fundamental frequency voltage and Vn is nth harmonic voltage component.

Major Causes Of Harmonics

Devices that draw non-sinusoidal currents when a sinusoidal voltage is applied create harmonics.Frequently these are devices that convert AC to DC. Some of these devices are listed below:

Electronic Switching Power Converters

- Computers, Uninterruptible power supplies (UPS), Solid-state rectifiers
- Electronic process control equipment, PLC’s, etc

• Electronic lighting ballasts, including light dimmer
• Reduced voltage motor controllers

Arcing Devices

• Discharge lighting, e.g. Fluorescent, Sodium and Mercury vapor
• Arc furnaces, Welding equipment, Electrical traction system

Ferromagnetic Devices

• Transformers operating near saturation level
• Magnetic ballasts (Saturated Iron core)
• Induction heating equipment, Chokes, Motors

Appliances

• TV sets, air conditioners, washing machines, microwave ovens
• Fax machines, photocopiers, printers

These devices use power electronics like SCRs, diodes, and thyristors, which are a growing percentage of the load in industrial power systems. The majority use a 6-pulse converter. Most loads which produce harmonics, do so as a steady-state phenomenon. A snapshot reading of an operating load that is suspected to be non-linear can determine if it is producing harmonics.Normally each load would manifest a specific harmonic spectrum.Many problems can arise from harmonic currents in a power system. Some problems are easy to detect; others exist and persist because harmonics are not suspected. Higher RMS current and voltage in the system are caused by harmonic currents, which can result in any of the problems listed below:

1. Blinking of Incandescent Lights - Transformer Saturation
2. Capacitor Failure - Harmonic Resonance
3. Circuit Breakers Tripping - Inductive Heating and Overload
4. Conductor Failure - Inductive Heating
5. Electronic Equipment Shutting down - Voltage Distortion
6. Flickering of Fluorescent Lights - Transformer Saturation
7. Fuses Blowing for No Apparent Reason - Inductive Heating and Overload
8. Motor Failures (overheating) - Voltage Drop
9. Neutral Conductor and Terminal Failures - Additive Triplen Currents
10. Electromagnetic Load Failures - Inductive Heating
11. Overheating of Metal Enclosures - Inductive Heating
12. Power Interference on Voice Communication - Harmonic Noise
13. Transformer Failures - Inductive Heating

Overcoming Harmonics

Tuned Harmonic filters consisting of a capacitor bank and reactor in series are designed and adopted for suppressing harmonics, by providing low impedance path for harmonic component.

1. Electrical System

The Harmonic filters connected suitably near the equipment generating harmonics help to reduce THD to acceptable limits. In present Indian context where no Electro Magnetic Compatibility regulations exist as a application of Harmonic filters is very relevant for industries having diesel power generation sets and co-generation units.

III.Energy efficient motors

Need of the energy motors arises

1.when there is a need for new installation or modification to existing system.
2.Old motors are damaged and need rewinding.
3.Existing motors are under loaded or over loaded.
4.to protect other devices

Energy-efficient motors (EEM) are the ones in which, design improvements are incorporated specifically to increase operating efficiency over motors of standard design[1,2]. Design improvements focus on reducing intrinsic motor losses. Improvements include the use of lower-loss silicon steel, a longer core (to increase active material), thicker wires (to reduce resistance), thinner laminations, smaller air gap between stator and rotor, copper instead of aluminum bars in the rotor, superior bearings and a smaller fan. The efficiency curves for standard motors and Energy efficiency motors[3,4] are as shown in FIG.1.

From the table.3, it may be noted that required capacitive kVAr increases with decrease in speed of the motor, as the magnetizing current requirement of a low speed motor is more in common.

IV.Labeling of Energy Efficiency motors

The Objectives of Standards & Labeling Program is to provide the consumer an informed choice about the energy saving and thereby the cost saving potential of the marketed household and other equipment. This is expected to impact the energy savings in the medium and long run while at the same time it will position domestic industry to compete in such markets where norms for energy

Efficiency. This scheme is launched and is currently invoked for equipments/appliances Room Air Conditioner (Fixed Speed), Ceiling Fan, Colour Television, Computer, Direct Cool Refrigerator, Distribution Transformer, Domestic Gas Stove, Frost Free Refrigerator, General Purpose Industrial Motor, Monoset Pump, Openwell Submersible Pump Set, Stationary Type Water Heater, Submersible Pump Set, Tfl, Washing Machine, Ballast, Solid State Inverter, Office Automation Products, Diesel Engine Driven Monosetpumps For Agricultural Purposes, Diesel Generator Set, Led Lamps, Room Air Conditioner (Variable Speed), Chiller, Variable Refrigerant Flow, Agricultural Pumpset, Microwave OvenSTAR Labeling of Energy Efficient Induction motors Based on IS 12615:2011 are (IE2,IE2(+),IE3,IE3+ and IE3(++) .Labeling should cover the following 1.Rated output (rating) 2.requirements for energy label validity 3.Test report format 4. Label should contain label design and details. The rating of star system is shown in Table.4.IE2 motors are energy efficiency motor, IE3 motor are premium energy efficiency motors. The efficiency for IE2 category is less compared to IE3 motors.

V.Advantages

1.Due to less consumption of power by motors, energy bill reduces.

2.Power factor of the plant improves due to direct installation of capacitor across induction motor.

VI.Conclusions

By replacing existing standard electric motors with Energy efficient motors

1.Energy can be saved from 3% to 7%.

2.Efficiency increases by 3 to 7 %

3.Life of the insulation doubles with every 10 degree centigrade decrease in operating temperature.

4.cost of Energy efficiency is 15% to 30% more than the standard motors.

5.In the future when the population of Energy efficiency motors increases the cost may come down to the cost of normal motors.

References

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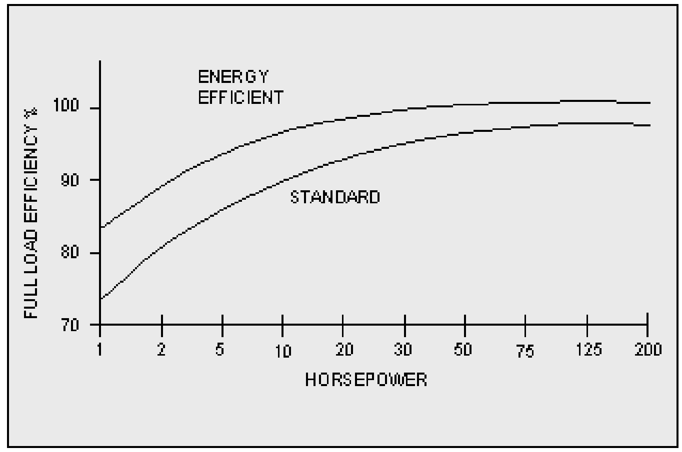

FIG.1

Table.1

THE EFFECT OF VOLTAGE UNBALANCE ON MOTOR PERFORMANCE			
Parameter	**Percent unbalance in voltage**		
	0.30	**2.30**	**5.40**
Unbalance in current (%)	0.4	17.7	40.0
Increased temperature rise (°C)	0	30	40

Table .2

ENERGY EFFICIENT MOTORS	
Power Loss Area	**Efficiency Improvement**
1. Iron	Use of thinner gauge, lower loss core steel reduces eddy current losses. Longer core adds more steel to the design, which reduces losses due to lower operating flux densities
2. Stator I2R	Use of more copper and larger conductors increases cross sectional area of stator windings. This lowers resistance (R) of the

	windings and reduces losses due to current flow (I).
3. Rotor I2R	Use of larger rotor conductor bars increases size of cross section, lowering conductor resistance (R) and losses due to current flow (I).
4. Friction & Windage	Use of low loss fan design reduces losses due to air movement.
5. Stray Load Loss	Use of optimized design and strict quality control procedures minimizes stray load losses.

Table .3

CAPACITOR RATINGS FOR POWER FACTOR CORRECTION BY DIRECT CONNECTION TO INDUCTION MOTORS						
Motor Rating (HP)	**Capacitor rating (kVAr) for Motor Speed**					
	3000	**1500**	**1000**	**750**	**600**	**500**
5	2	2	2	3	3	3
7.5	2	2	3	3	4	4
10	3	3	4	5	5	6
15	3	4	5	7	7	7
20	5	6	7	8	9	10
25	6	7	8	9	9	12
30	7	8	9	10	10	15
40	9	10	12	15	16	20
50	10	12	15	18	20	22
60	12	14	15	20	22	25
75	15	16	20	22	25	30
100	20	22	25	26	32	35
125	25	26	30	32	35	40
150	30	32	35	40	45	50
200	40	45	45	50	55	60
250	45	50	50	60	65	70

Table.4

Motor	Efficiency class-III	Efficiency class-II(IE2)	Efficiency class-I(IE3)
Rating	30HP	30HP	30HP
Efficiency	88	91.4	93.2
load	16.5	16.5	16.5
Motor	18.75	18.05	17.7
input			
Annual KWH used	1,64,250	1,58,118	1,55,052
Annual KWH saved	-	6132	9198
Annual RS. saved	-	30660	45,990