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ELECTRICAL POWER SYSTEMS - CEM

REFRESHER TRAINING

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FOR ENERGY MANAGEMENT AND EFFICIENCY PROFESSIONALS

ENERGY MANAGEMENT SPECIALIST

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ELECTRIC MOTORS - 1

FOR ENERGY PROFESSIONALS

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ENERGY SPECIALIST CURRICULUM

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WHAT SHOULD YOU LEARN



Introduction

Electric Motors Types

Losses in induction motors

Motor efficiency,

Factors affecting motor performance

Rewinding and motor replacement issues, Energy saving opportunities with energy efficient motors.

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INTRODUCTION

Motors convert electrical energy into mechanical energy by the interaction between the magnetic fields set up in the stator and rotor windings. Industrial electric motors can be broadly classified as induction motors, direct current motors or synchronous motors.

All motor types have the same four operating components: stator (stationary windings), rotor (rotating windings), bearings, and frame (enclosure).



MOTOR TYPES

Induction Motors :

Induction motors are the most commonly used prime mover for various equipments in industrial applications. In induction motors, the induced magnetic field of the stator winding induces a current in the rotor.



This induced rotor current produces a second magnetic field, which tries to oppose the stator magnetic field, and this causes the rotor to rotate.

The 3-phase squirrel cage motor is the workhorse of industry; it is rugged and reliable, and is by far the most common motor type used in industry. These motors drive pumps, blowers and fans, compressors, conveyers and production lines. The 3-phase induction motor has three windings each connected to a separate phase of the power supply.



MOTOR TYPES +

Direct-Current:

Motors Direct-Current motors, as the name implies, use direct unidirectional, current. Direct current motors are used in special applications- where high torque starting or where smooth acceleration over a broad speed range is required.

Synchronous Motors :

AC power is fed to the stator of the synchronous motor. The rotor is fed by DC from a separate source. The rotor magnetic field locks onto the stator rotating magnetic field and rotates at the same speed. The speed of the rotor is a function of the supply frequency and the number of magnetic poles in the stator. While induction motors rotate with a slip, i.e., rpm is less than the synchronous speed, the synchronous motor rotate with no slip, i.e., the rpm is same as the synchronous speed governed by supply frequency and number of poles. The slip energy is provided by the D.C. excitation power



MOTOR CHARACTERISTICS

Motor Speed :

The speed of a motor is the number of revolutions in a given time frame, typically revolutions per minute (RPM). The speed of an AC motor depends on the frequency of the input power and the number of poles for which the motor is wound. The synchronous speed in RPM is given by the following equation, where the frequency is in hertz or cycles per second:

$$\text{Synchronous Speed (RPM)} = 120 \times \text{Frequency} / \text{No. of Poles}$$

As per relation stated above, the speed of an AC motor is determined by the number of motor poles and by the input frequency. It can also be seen that theoretically speed of an AC motor can be varied infinitely by changing the frequency. Manufacturer's guidelines should be referred for practical limits to speed variation. With the addition of a Variable Frequency Drive (VFD), the speed of the motor can be decreased as well as increased.

POWER FACTOR

Power Factor The power factor of the motor is given as:

$$\text{Power Factor} = \cos \phi = \text{kW} / \text{kVA}$$

As the load on the motor comes down, the magnitude of the active current reduces. However, there is no corresponding reduction in the magnetizing current, which is proportional to supply voltage with the result that the motor power factor reduces, with a reduction in applied load. Induction motors, especially those operating below their rated capacity, are the main reason for low power factor in electric systems.

MOTOR EFFICIENCY

Two important attributes relating to efficiency of electricity use by A.C. Induction motors are efficiency (η), defined as the ratio of the mechanical energy delivered at the rotating shaft to the electrical energy input at its terminals, and power factor (PF).

Motors, like other inductive loads, are characterised by power factors less than one. As a result, the total current draw needed to deliver the same real power is higher than for a load characterised by a higher PF. An important effect of operating with a PF less than one is that resistance losses in wiring upstream of the motor will be higher, since these are proportional to the square of the current. Thus, both a high value for η and a PF close to unity are desired for efficient overall operation in a plant.

MOTOR EFFICIENCY +

✓The efficiency of a motor is determined by intrinsic losses that can be reduced only by changes in motor design. Intrinsic losses are of two types: fixed losses - independent of motor load, and variable losses dependent on load.

✓Fixed losses consist of magnetic core losses and friction and windage losses. Magnetic core losses (sometimes called iron losses) consist of eddy current and hysteresis losses in the stator. They vary with the core material and geometry and with input voltage. Friction and windage losses are caused by friction in the bearings of the motor and aerodynamic losses associated with the ventilation fan and other rotating parts.

✓Variable losses consist of resistance losses in the stator and in the rotor and miscellaneous stray losses. Resistance to current flow in the stator and rotor result in heat generation that is proportional to the resistance of the material and the square of the current (I^2R). Stray losses arise from a variety of sources and are difficult to either measure directly or to calculate, but are generally proportional to the square of the rotor current.

MOTOR EFFICIENCY +

✓Field Tests for Determining Efficiency No Load Test: The motor is run at rated voltage and frequency without any shaft load. Input power, current, frequency and voltage are noted. The no load P.F. is quite low and hence low PF wattmeters are required. From the input power, stator I^2R losses under no load are subtracted to give the sum of Friction and Windage (F&W) and core losses

✓Stator and Rotor I^2R Losses: The stator winding resistance is directly measured by a bridge or volt amp method. The resistance must be corrected to the operating temperature. For modern motors, the operating temperature is likely to be in the range of 100°C to 120°C and necessary correction should be made. Correction to 75°C may be inaccurate. The correction factor is given as follows :

$R_2 / R_1 = 235 + t_2 / 235 + t_1$ T, where, t_1 = ambient temperature, $^{\circ}\text{C}$ & t_2 = operating temperature, $^{\circ}\text{C}$. The rotor resistance can be determined from locked rotor test at reduced frequency, but rotor I^2R losses are measured from measurement of rotor slip.

Rotor I^2R losses = Slip $\times$ (Stator Input - Stator I^2R Losses - Core Loss)

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