Twenty Ways to Optimize Energy Efficiency in the Use of Induction Motors

An Online Continuing Education Course for Engineers

Course Number: E-6004

Credit: 6 Hours / 6 PDH / 6 CPD

Twenty Ways to Optimize Energy Efficiency in the Use of Induction Motors

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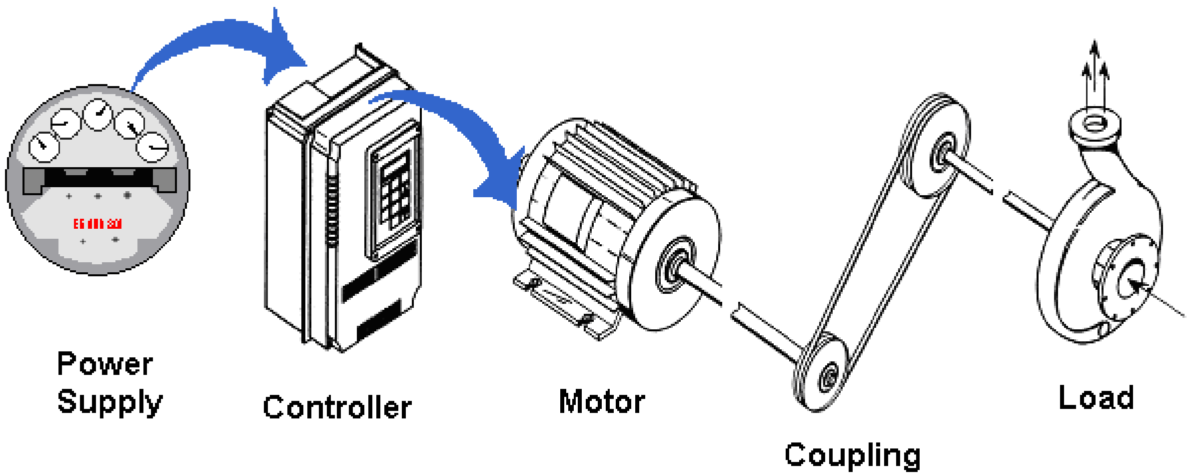
Electric motors convert electrical energy into mechanical energy. This energy is then used to drive a fan, a compressor, a pump or another rotating or oscillating part.

A motor-driven system consists of several components: the electrical power supply, motor controls, the electric motor, and a mechanical transmission system. For example, the heating, ventilating, and air conditioning (HVAC) systems use single or three-phase electrical motors to supply mechanical energy through shafts or belts to compressors, pumps and fans.



Each component of this system can be optimized for reliability and efficiency.

This course is designed to identify opportunities to improve motor and motor-drive system efficiency. It provides 20 different strategies to guide you into the electric motor evaluation process and highlights common ways you can improve system efficiency and reliability to achieve permanent long-term electric cost reduction. The concepts range from basic power quality issues, transmission efficiencies and monitoring and maintenance. The categories provide a series of steps for checking each of your motors.

Motor Basics Overview

A motor will draw as much power and consume as much energy as it requires moving the load.

$$\text{Motor Energy} = \frac{(\text{Motor Load}) \times (\text{Operating Time})}{(\text{Motor Efficiency})}$$

and

Motor load (hp) = $\sqrt{3} \times V \times I \times pf \times Eff / 0.746$

Where

- hp = horsepower
- V = voltage
- I = curent (amps)
- pf = power factor
- Eff. = efficiency

Efficiency expresses the energy losses inherent in the construction of the motor, and the ratio of power delivered at the shaft to power input. ‘

Power factor is a form of electrical efficiency due to voltage and current waveforms being out of phase with each other. It is the ratio of real power input (watts) to the product of the actual current and voltage (volt-amperes). Induction motors have a lagging power factor below unity.

Typically motors can be classed into two categories, alternating current (AC) type or direct current (DC) type. The basic motor principles are alike for both the AC and DC motor. Magnetism is the basis for all electric motor operation. It produces the forces necessary for the motor to run.

Not all motors are alike, and the different types have different applications and efficiencies. The three-phase, alternating-current induction motors because of relatively low-cost, low-maintenance, and straightforward simplicity make them a preferred choice for most of the applications.

This course will focus on the fundamental principles for operation of these types of motors.

Concepts and Construction

The basic principle of operation for all motors is electromagnetism. When the electric current flows through a conductor such as a copper wire, it produces a magnetic field, which causes the motion. The prime link between electricity and magnetism is motion. Insulating materials such as paper and plastics are used to separate the magnetic and electrical circuits.

Three-phase induction motors are built with two basic components: the rotor and the stator. The rotor is made up of the shaft, rotor core (a stack of steel laminations that form slots and aluminum conductors and end rings formed by either a die cast or fabrication process) and sometimes a fan. This is the rotating part of the electromagnetic circuit. A fabricated rotor core with air ducts is shown below.

The other major part is the stator. The stator consists of a laminated iron core in the shape of a hollow cylinder, with internal slots so that insulated conductor windings from each of the three phases may be inserted into them.

Insulation is inserted to line the slots, and then coils wound with many turns of wire are inserted into the slots to form a circuit.

When balanced three-phase voltage is applied to the windings of the stator, the balanced three-phase currents flows in three interconnected phase windings. These currents produce a magnetic field which results in torque to turn the rotor. *In the most common type of electric motor, AC induction, electric power is not conducted to the rotor directly, but receives its power inductively. The construction of induction motors are dominated by this principle.*

Three-phase current refers to a typical configuration of power distribution where three wires conduct three separate electrical phases. The current flow in the three-phase wires is offset from each other by 120 degrees of each 360-degree cycle. Since the stator windings connect to these separate phases, the magnetic field they produce rotates by virtue of their common 120-degree displacement, even though the stator itself is stationary. The current flowing in each supply conductor alternates direction along the conductor with a frequency of 60 cycles /sec (Hz), referred to as alternating current (AC).

Each of the three phases of stator winding is arranged in pairs called poles. The number of poles in the stator determines the speed at which the rotor rotates: "the greater the number of poles, the slower the rotation." This is because the circumferential distance between poles is shorter with a greater number of poles. The rotor, therefore, can move slower to "keep up" with the rotating magnetic field. The speed of the motor's magnetic field (referred to as the synchronous speed), in revolutions per minute (RPM) is calculated using the following equation:

$$N = \frac{120f}{P}$$

- N = rotational speed of stator magnetic field in RPM (synchronous speed)
- f = frequency of the stator current flow in Hz
- P = number of motor magnetic poles

Standard RPM's are as follows:

TYPICAL ACTUAL SPEED	SYNCHRONOUS SPEED	NUMBER OF POLES
3530	3600	2
1750	1800	4
1175	1200	6
880	900	8

At no-load the rotor will turn at a speed y equal to N. In order to produce torque, the rotor in an induction motor must rotate slower than the magnetic field. The difference between rotor speed and synchronous speed is called '*Slip*', usually expressed as a percentage of synchronous speed. Therefore, the actual speed of a motor with a synchronous speed of 1,800 rpm is generally 1,750 rpm. Slip is defined by equation:

%age Slip = (Synchronous Speed – Rotor Speed) x 100 / Synchronous Speed

Thus speed of an AC motor is determined by two factors: the applied frequency and the number of poles. In most cases the number of poles is constant and the only way to vary the speed is to change the applied frequency. Changing the frequency is the primary function of an AC drive.

Types of Motor

There are several major classifications of motors in common use, each with specification characteristics that suit it to particular applications. The motor classification based on power input is either alternating current (AC) motors or the direct current (DC) motors.

Alternating Current (AC) Motor Types

AC motors can be divided into two main types: induction and synchronous.

Induction Motors

Induction Motors (3-phase) are the most widely used motors in ind commercial applications. Induction motors are simple bec ical rotor connection. An additional start

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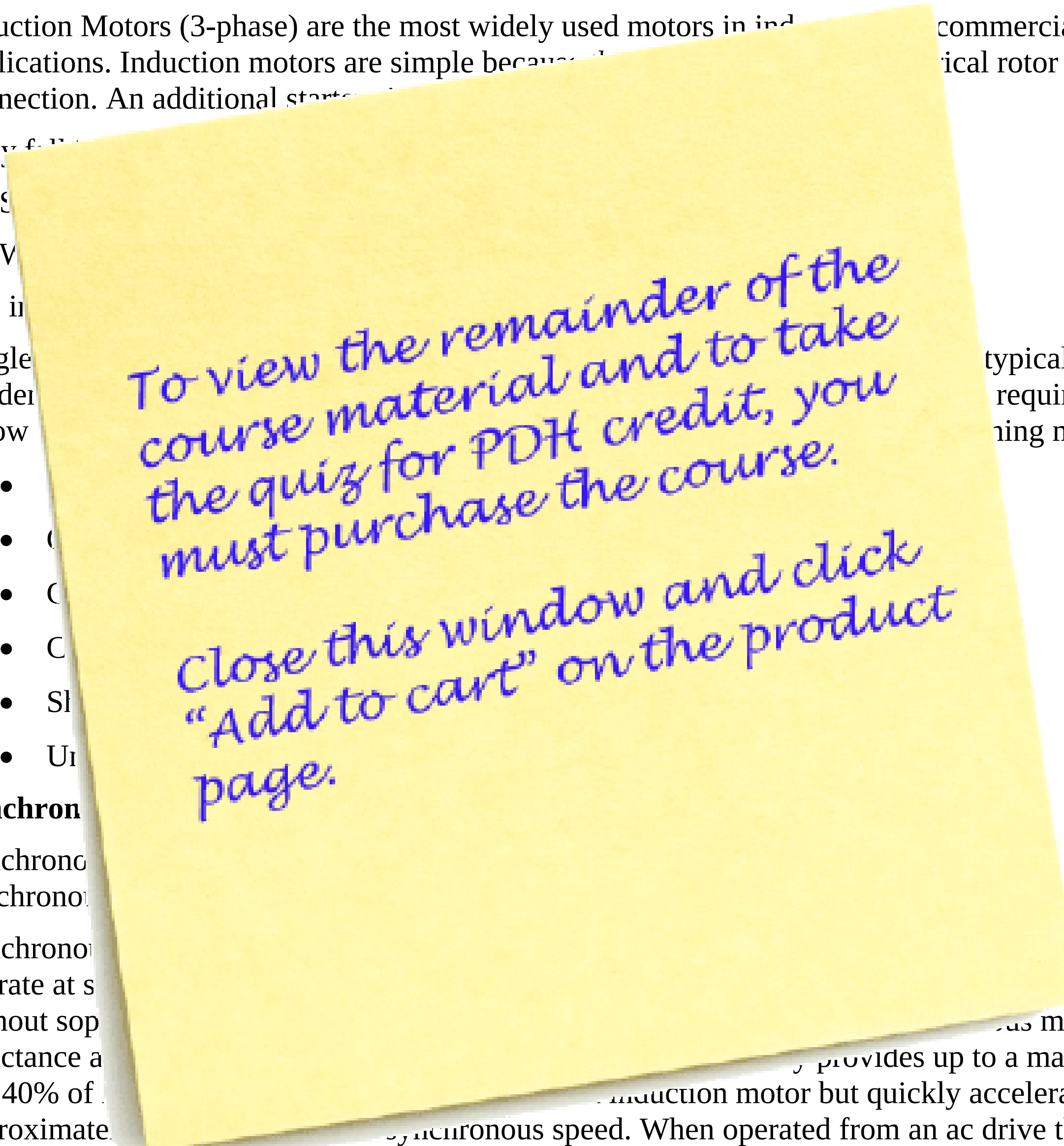

Standard designs of Induction Motors based on NEMA

A motor's rotor must turn slower than the rotating magnetic field in the stator to induce an electrical current in the rotor conductor bars and thus produce torque. When the load on the