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Welcome to Basics of AC Motors. This course covers the following topics:

Chapter 1 - Introduction
  • Basic Concepts

Chapter 2 – Motor Basics
  • Electromagnetism
  • Rotor Rotation

Chapter 3 – NEMA Motors
  • Motor Designs
  • Motor Enclosures

Chapter 4 – Siemens Motors
  • NEMA Motors
  • IEC Motors
  • Above NEMA Motors

If you do not have an understanding of basic electrical concepts, you should complete Basics of Electricity before attempting this course.
Course Objectives

Upon completion of this course you will be able to…
• Explain the concepts of force, inertia, speed, and torque
• Explain the difference between work and power
• Describe the construction of a squirrel cage AC motor
• Describe the operation of a rotating magnetic field
• Calculate synchronous speed, slip, and rotor speed
• Identify the starting torque, pull-up torque, breakdown torque, and full-load torque on a NEMA B motor speed-torque curve
• Describe the information displayed on a NEMA motor nameplate
• Identify important motor derating factors
• Identify NEMA enclosures and mounting configurations
• Summarize the types of Siemens SIMOTICS motors available
This course primarily focuses on building your basic knowledge of NEMA three-phase induction motors, which are part of Siemens extensive SIMOTICS motor product line. SIMOTICS industrial electric motors provide you with the optimum solution for every application. Backed by 150 years of experience, SIMOTICS motors are unrivaled when it comes to reliability, ruggedness, compactness, efficiency, and performance. SIMOTICS electric motors include:

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Chapter 1 – Introduction

This chapter covers the following topic:

• Basic Concepts
• AC Motor Construction
AC motors are used worldwide in many applications to transform electrical energy into mechanical energy. There are many types of AC motors, but this course focuses on three-phase induction motors, the most common type of motor used in industrial applications.

An AC motor of this type may be part of a pump or fan or connected to some other form of mechanical equipment such as a winder, conveyor, or mixer. Siemens manufactures a wide variety of AC motors.

In addition to providing basic information about AC motors in general, this course also includes an overview of Siemens SIMOTICS NEMA AC motors, which range from general purpose motors in Aluminum frame, to sophisticated three-phase motors that meet or exceed IEEE 841 and NEMA Premium® standards.

Some summary information is also included for Siemens IEC and Above NEMA motors.
Throughout this course, reference is made to the National Electrical Manufacturers Association (NEMA). NEMA develops standards for a wide range of electrical products, including AC motors. For example, NEMA Standard Publication MG 1 covers NEMA frame size AC motors, commonly referred to as NEMA motors.

In addition to manufacturing NEMA motors, Siemens also manufactures motors larger than the largest NEMA frame size. These motors are built to meet specific application requirements and are commonly referred to as above NEMA motors.

Siemens also manufactures motors to International Electrotechnical Commission (IEC) standards. IEC is another organization responsible for electrical standards. IEC standards perform the same function as NEMA standards, but differ in many respects. In many countries, electrical equipment is commonly designed to comply with IEC standards. In the United States, although IEC motors are used, NEMA motors are more common. Keep in mind, however, that many U.S.-based companies build products for export to countries that follow IEC standards.
Before discussing AC motors and drives, it is necessary to discuss some of the basic terminology associated with their operation.

In simple terms, a force is a push or pull. Force may be caused by electromagnetism, gravity, or a combination of physical means.

Net force is the vector sum of all forces that act on an object, including friction and gravity. When forces are applied in the same direction, they are added.

For example, if two 10 pound forces are applied in the same direction, the net force is 20 pounds. If 10 pounds of force is applied in one direction and 5 pounds of force is applied in the opposite direction, the net force is 5 pounds, and the object moves in the direction of the greater force. If 10 pounds of force is applied equally in both directions, the net force is zero, and the object does not move.
Torque is a twisting or turning force that causes an object to rotate. For example, a force applied to a point on a lever applies a torque at the pivot point.

Torque is the product of force and radius (lever distance).

\[ \text{Torque} = \text{Force} \times \text{Radius} \]

In the English system of measurements, torque is measured in pound-feet (lb-ft) or pound-inches (lb-in). For example, if 10 lbs of force is applied to a lever 1 foot long, the resulting torque is 10 lb-ft.

An increase in force or radius results in a corresponding increase in torque. Increasing the radius to two feet, for example, results in 20 lb-ft of torque.
Speed

An object in motion takes time to travel any distance. Speed is the ratio of the distance traveled and the time it takes to travel the distance.

Linear speed is the rate at which an object travels a specified distance in one direction. Linear speed is expressed in units of distance divided by units of time.

This results in compound speed units such as miles per hour or meters per second (m/s). Therefore, if it takes 2 seconds to travel 10 meters, the speed is 5 m/s.
Angular Speed

The angular speed, also called rotational speed, of a rotating object determines how long it takes for an object to rotate a specified angular distance.

Angular speed is often expressed in revolutions per minute (RPM). For example, an object that makes ten complete revolutions in one minute has a speed of 10 RPM.

\[
\text{Angular or Rotational Speed} = \frac{\text{Distance}}{\text{Time}} = \frac{\text{Degrees, Radians, or Revolutions}}{\text{Time}}
\]

Example: \( \frac{10 \text{ Revolutions}}{1 \text{ Minute}} = 10 \text{ RPM} \)
An increase in speed is called acceleration. Acceleration occurs when there is an increase in the force acting on the object or a reduction in its resistance to motion.

A decrease in speed is called deceleration. Deceleration occurs when there is a decrease in the force acting on and object or an increase in its resistance to motion.

For example, a rotating object can accelerate from 10 RPM to 20 RPM or decelerate from 20 RPM to 10 RPM.
Mechanical systems are subject to the law of inertia. The law of inertia states that an object will remain in its current state of rest or motion unless acted upon by an external force. This property of resistance to acceleration and deceleration is referred to as the moment of inertia. The English system unit of measurement for inertia is pound-feet squared.

For example, consider a machine that unwinds a large roll of paper. If the roll is not moving, it takes a force to overcome inertia and start the roll in motion. Once moving, it takes a force in the reverse direction to bring the roll to a stop.

Any system in motion has losses that drain energy from the system. The law of inertia is still valid, however, because the system will remain in motion at constant speed if energy is added to the system to compensate for the losses.

Friction is one of the most significant causes of energy loss in a machine. Friction occurs when objects contact one another. For example, to move one object across the surface of another object, you must apply enough force to overcome friction.
Whenever a force causes motion, work is accomplished. Work is calculated by multiplying the force that causes the motion times the distance the force is applied.

Because work is the product of force times the distance applied, work can be expressed in any compound unit of force times distance. For example, work is commonly expressed in joules. 1 joule is equal to 1 newton-meter, a force of 1 newton for a distance of 1 meter. In the English system of measurements, work is often expressed in foot-pounds (ft-lb), where 1 ft-lb equals 1 foot times 1 pound.

Another often used quantity is power. Power is the rate of doing work, which is the amount of work done in a period of time.
Horsepower and Kilowatts

Power can be expressed in foot-pounds per second, but is often expressed in horsepower. This unit was defined in the 18th century by James Watt. Watt sold steam engines and was asked how many horses one steam engine would replace. He had horses walk around a wheel that would lift a weight. He found that a horse would average about 550 foot-pounds of work per second. Therefore, one horsepower is equal to 550 foot-pounds per second or 33,000 foot-pounds per minute.

When applying the concept of horsepower to motors, it is useful to determine the amount of horsepower for a given amount of torque and speed. When torque is expressed in lb-ft and speed is expressed in RPM the formula for horsepower (HP) shown in the accompanying graphic can be used. Note that a change in torque or speed also changes horsepower.

AC motors manufactured in the United States are generally rated in horsepower, but motors manufactured in many other countries are rated in kilowatts (kW). Fortunately it is easy to convert between these units as shown in the accompanying graphic.
Chapter 1 – Introduction

This chapter covers the following topic:

• Basic Concepts
• AC Motor Construction
Three-phase induction motors are commonly used in industrial applications. This type of motor has the following three main parts: rotor, stator, and enclosure. The stator and rotor do the work, and the enclosure protects the stator and rotor.
The stator is the stationary part of the motor’s electromagnetic circuit. The stator core is made up of many thin metal sheets, called laminations. Laminations are used to reduce energy loses that would result if a solid core were used.
Stator laminations are stacked together forming a hollow cylinder. Coils of insulated wire are inserted into slots of the stator core.

When the assembled motor is in operation, the stator windings are connected directly to the power source. Each grouping of coils, together with the steel core it surrounds, becomes an electromagnet when current is applied. Electromagnetism is the basic principle behind motor operation.
The rotor is the rotating part of the motor's electromagnetic circuit. The most common type of rotor used in a three-phase induction motor is a squirrel cage rotor.

The squirrel cage rotor is so called because its construction is reminiscent of the rotating exercise wheels found in some pet cages. A squirrel cage rotor core is made by stacking thin steel laminations to form a cylinder.
Rather than using coils of wire as conductors, conductor bars are die cast into the slots evenly spaced around the cylinder. Most squirrel cage rotors are made by die casting aluminum to form the conductor bars. Siemens also makes motors with die cast copper rotor conductors.

After die casting, rotor conductor bars are mechanically and electrically connected with end rings. The rotor is then pressed onto a steel shaft to form a rotor assembly.
The enclosure consists of a frame (or yoke) and two end brackets (or bearing housings). The stator is mounted inside the frame. The rotor fits inside the stator with a slight air gap separating it from the stator. There is no direct physical connection between the rotor and the stator.

The enclosure protects the internal parts of the motor from water and other environmental elements. The degree of protection depends upon the type of enclosure. Enclosure types are discussed later in this course.
Bearings and Fan

Bearings, mounted on the shaft, support the rotor and allow it to turn. Some motors, like the one shown in the accompanying illustration, use a fan, also mounted on the rotor shaft, to cool the motor when the shaft is rotating.
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Chapter 2 – Motor Basics

This chapter covers the following topics:

- Electromagnetism
- Rotor Rotation
The principles of magnetism play an important role in the operation of an AC motor. Therefore, in order to understand motors, you must understand magnets.

To begin with, all magnets have two characteristics. They attract iron and steel objects, and they interact with other magnets. This later fact is illustrated by the way a compass needle aligns itself with the Earth’s magnetic field.
The force that attracts an iron or steel object has continuous magnetic field lines, called lines of flux, that run through the magnet, exit the north pole, and return through the south pole.

Although these lines of flux are invisible, the effects of magnetic fields can be made visible. For example, when a sheet of paper is placed on a magnet and iron filings are loosely scattered over the paper, the filings arrange themselves along the invisible lines of flux.
Magnetic Poles

The polarities of magnetic fields affect the interaction between magnets. For example, when the opposite poles of two magnets are brought within range of each other, the lines of flux combine and pull the magnets together.

However, when like poles of two magnets are brought within range of each other, their lines of flux push the magnets apart. In summary, unlike poles attract and like poles repel. The attracting and repelling action of the magnetic fields is essential to the operation of AC motors.
When current flows through a conductor, it produces a magnetic field around the conductor. The strength of the magnetic field is proportional to the amount of current.
Left Hand Rule for Conductors

The left hand rule for conductors demonstrates the relationship between the flow of electrons and the direction of the magnetic field created by this current. If a current-carrying conductor is grasped with the left hand with the thumb pointing in the direction of electron flow, the fingers point in the direction of the magnetic lines of flux.

The accompanying illustration shows that, when the electron flow is away from the viewer (as indicated by the plus sign), the lines of flux flow in a counterclockwise direction around the conductor. When the electron flow reverses and current flow is towards the viewer (as indicated by the dot), the lines of flux flow in a clockwise direction.
An electromagnet can be made by winding a conductor into a coil and applying a DC voltage. Because the coil concentrates the lines of flux formed by current flow through the conductor, the magnetic field in or near the coil is strengthened. The center of the coil is known as the core. This simple electromagnet has an air core.
Iron conducts magnetic flux more easily than air. When an insulated conductor is wound around an iron core, a stronger magnetic field is produced for the same level of current.

The strength of the magnetic field created by the electromagnet can be increased further by increasing the number of turns in the coil. The greater the number of turns, the stronger the magnetic field for the same level of current.
Applying an AC Source

The magnetic field of an electromagnet has the same characteristics as a natural magnet, including a north and south pole. However, when the direction of current flow through the electromagnet changes, the polarity of the electromagnet changes. As shown in the accompanying graphic, the polarity of an electromagnet connected to an AC source changes at the frequency of the AC source.

At time 1, there is no current flow, and no magnetic field is produced. At time 2, current is flowing and a magnetic field builds up around the electromagnet. Note that the south pole is on the top and the north pole is on the bottom. At time 3, current flow is at its peak, and the strength of the magnetic field has also peaked. At time 4, current flow decreases, and the magnetic field begins to collapse.

At time 5, no current is flowing and no magnetic field is produced. At time 6, current is increasing in the opposite direction. Note that the polarity of the electromagnetic field has changed, and the north pole is now on the top. The negative half of the cycle continues through times 7 and 8, returning to zero at time 9. For a 60 Hertz AC power supply, this process repeats 60 times a second.
In the previous examples, the coil was directly connected to a power supply. However, a voltage can be induced across a conductor by merely moving it through a magnetic field. This same effect is caused when a stationary conductor encounters a changing magnetic field. This electrical principle is critical to the operation of AC induction motors.

In the accompanying graphic, an electromagnet is connected to an AC power source. Another electromagnet is placed above it. The second electromagnet is in a separate circuit and there is no physical connection between the two circuits.

This graphic shows the build up of magnetic flux during the first quarter of the AC waveform. At time 1, voltage and current are zero in both circuits. At time 2, voltage and current are increasing in the bottom circuit. As magnetic field builds up in the bottom electromagnet, lines of flux from its magnetic field cut across the top electromagnet and induce a voltage across the electromagnet. This causes current to flow through the ammeter. At time 3, current flow has peaked in both circuits. As in the previous example, the magnetic field around each coil expands and collapses in each half cycle and reverses polarity from one half cycle to another.
Electromagnetic Attraction

In the accompanying graphic, note that the polarity of the magnetic field in the top electromagnet is opposite the polarity of the magnetic field in the bottom electromagnet.

Because opposite poles attract, the two electromagnets attract each other whenever flux has built up. If the bottom electromagnet is moved, and the magnetic field is strong enough, the top electromagnet is pulled along with it.
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This chapter covers the following topics:

- Electromagnetism
- Rotor Rotation
The principles of electromagnetism explain the shaft rotation of an AC motor. Recall that the stator of an AC motor is a hollow cylinder in which coils of insulated wire are inserted.

The lower part of the accompanying diagram shows the electrical configuration of stator windings. In this example, six windings are used, two for each of the three phases. The coils are wound around the soft iron core material of the stator. When current is applied, each winding becomes an electromagnet, with the two windings for each phase operating as the opposite ends of one magnet.

In other words, the coils for each phase are wound in such a way that, when current is flowing, one winding is a north pole and the other is a south pole. For example, when A1 is a north pole, A2 is a south pole and, when current reverses direction, the polarities of the windings also reverse.
Stator Power Source

The stator is connected to a three-phase AC power source. The following illustration shows windings A1 and A2 connected to phase A of the power supply.

When the connections are completed, B1 and B2 will be connected to phase B, and C1 and C2 will be connected to phase C.
Stator Phases

As the accompanying illustration shows, coils A1, B1, and C1 are 120° apart. Note that windings A2, B2, and C2 also are 120° apart. This corresponds to the 120° separation between each electrical phase. Because each phase winding has two poles, this is called a two-pole stator.

When AC voltage is applied to the stator, the magnetic field developed in a set of phase coils depends on the direction of current flow as shown in the accompanying chart. This chart assumes that a positive current flow in the A1, B1 or C1 windings results in a north pole. The vector sum of magnetic fields in any instant of time is called the resultant magnetic field. The next few pages of this course show how that resultant magnetic field rotates as the currents applied to each winding vary.
In the accompanying graphic, a start time has been selected during which phase A has no current flow and its associated coils have no magnetic field. Phase B has current flow in the negative direction and phase C has current flow in the positive direction.

Based on the previous chart, B1 and C2 are south poles and B2 and C1 are north poles. Magnetic lines of flux leave the B2 north pole and enter the nearest south pole, C2. Magnetic lines of flux also leave the C1 north pole and enter the nearest south pole, B1. The vector sum of the magnetic fields is indicated by the arrow.
The accompanying graphic shows the progress of the magnetic field vector as each phase has advanced 60°. Note that at time 1 phase C has no current flow, and no magnetic field has developed in C1 and C2.

Phase A has current flow in the positive direction and phase B has current flow in the negative direction. This means that windings A1 and B2 are north poles and windings A2 and B1 are south poles. The resultant magnetic field vector has rotated 60° in the clockwise direction.
At time 2, phase B has no current flow and windings B1 and B2 have no magnetic field. Current in phase A is flowing in the positive direction, but phase C current is now flowing in the negative direction. The resultant magnetic field vector has rotated another 60°.
At the end of six such time intervals, the magnetic field has rotated one full revolution. This process repeats 60 times a second for a 60 Hz power source.
The speed of the rotating magnetic field is referred to as the synchronous speed \((N_s)\) of the motor. Synchronous speed in RPM is equal to 120 times the frequency \((F)\) in hertz, divided by the number of motor poles \((P)\).

As shown in the accompanying graphic, the synchronous speed for a two-pole motor operated at 60 Hz is 3600 RPM.

Synchronous speed decreases as the number of poles increases. The accompanying table shows the synchronous speed at 50 and 60 Hz for several different pole numbers.
To see how a rotor works, a magnet mounted on a shaft can be substituted for the squirrel cage rotor. When the stator windings are energized, a rotating magnetic field is established. The magnet has its own magnetic field that interacts with the rotating magnetic field of the stator. The north pole of the rotating magnetic field attracts the south pole of the magnet, and the south pole of the rotating magnetic field attracts the north pole of the magnet. As the magnetic field rotates, it pulls the magnet along.

AC motors that use a permanent magnet for a rotor are referred to as permanent magnet synchronous motors. The term synchronous means that the rotor’s rotation is synchronized with the magnetic field, and the rotor’s speed is the same as the motor’s synchronous speed.
Instead of a permanent magnet rotor, a squirrel cage induction motor induces a current in its rotor, creating an electromagnet.

As the accompanying graphic shows, when current is flowing in a stator winding, the electromagnetic field created cuts across the nearest rotor bars.
Squirrel Cage Rotor

When a conductor, such as a rotor bar, passes through a magnetic field, a voltage (electromotive force or emf) is induced in the conductor. The induced voltage causes current flow in the conductor. In a squirrel cage rotor, current flows through the rotor bars and around the end ring and produces a magnetic field around each rotor bar.

Because the stator windings are connected to an AC source, the current induced in the rotor bars continuously changes and the squirrel cage rotor bars become electromagnets with alternating north and south poles.
The following illustration shows an instant when winding A1 is a north pole and its field strength is increasing. The expanding field cuts across an adjacent rotor bar, inducing a voltage. The resultant current flow in one rotor bar produces a south pole. This causes the motor to rotate towards the A1 winding.

At any given point in time, the magnetic fields for the stator windings are exerting forces of attraction and repulsion against the various rotor bars. This causes the rotor to rotate, but not exactly at the motor’s synchronous speed.
Slip

For a three-phase induction motor, the rotating magnetic field must rotate faster than the rotor to induce current in the rotor. When power is first applied to the motor with the rotor stopped, this difference in speed is at its maximum and a large amount of current is induced in the rotor.

After the motor has been running long enough to get up to operating speed, the difference between the synchronous speed of the rotating magnetic field and the rotor speed is much smaller. This speed difference is called slip.

Slip is necessary to produce torque. Slip is also dependent on load. An increase in load causes the rotor to slow down, increasing slip. A decrease in load causes the rotor to speed up, decreasing slip.

Slip is expressed as a percentage and can be calculated using the formula shown in the accompanying illustration.

For example, a four-pole motor operated at 60 Hz has a synchronous speed ($N_S$) of 1800 RPM. If its rotor speed ($N_R$) at full load is 1765 RPM, then its full load slip is 1.9%.
The discussion to this point has been centered on the more common squirrel cage rotor. Another type of three-phase induction motor is the wound rotor motor. A major difference between the wound rotor motor and the squirrel cage rotor is that the conductors of the wound rotor consist of wound coils instead of bars. These coils are connected through slip rings and brushes to external variable resistors.

The rotating magnetic field induces a voltage in the rotor windings. Increasing the resistance of the rotor windings causes less current to flow in the rotor windings, decreasing rotor speed. Decreasing the resistance causes more current to flow, increasing rotor speed.
Another type of three-phase AC motor is the synchronous motor. The synchronous motor is not an induction motor. One type of synchronous motor is constructed somewhat like a squirrel cage rotor. In addition to rotor bars, coil windings are also used. The coil windings are connected to an external DC power supply by slip rings and brushes.

When the motor is started, AC power is applied to the stator, and the synchronous motor starts like a squirrel cage rotor. DC power is applied to the rotor coils after the motor has accelerated. This produces a strong constant magnetic field in the rotor which locks the rotor in step with the rotating magnetic field. The rotor therefore turns at synchronous speed, which is why this is a synchronous motor.

Some synchronous motors use a permanent magnet rotor. This type of motor does not need a DC power source to magnetize the rotor.
Studies indicate that when students practice what they have learned in a classroom setting they retain 75% of the lesson, as compared with lecture-only settings where they retain just 20% of the lesson.

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Chapter 3 – NEMA Motors

This chapter covers the following topics:

- Motor Designs
- Motor Application
- Motor Enclosures
A motor’s nameplate provides information necessary for proper application. For example, the accompanying graphic shows the nameplate for a Siemens GP100A, 3 horsepower (HP), NEMA 3-phase (3 PH) motor.

This is a NEMA motor, but it is also rated for operation in Europe, so it has North American ratings (outlined in red) and European ratings (outlined in blue). North American ratings also apply in some other areas where the power line frequency is 60 Hz, and European ratings also apply in some other areas where the power line frequency is 50 Hz.

Note that for both sets of ratings, this motor has low voltage connections and high voltage connections. For example, for 60 Hz applications this motor may be operated at 208 VAC or 230 VAC using the low voltage connections or at 460 VAC using the high voltage connections.

There are three full-load current (A) ratings for 60 Hz applications. For 208 VAC applications, the rated current is 8.5 A, for 230 VAC applications, the rated current is 8.0 A, and for 460 VAC applications, the rated current is 4.0 A. For 50 HZ applications, because there are only two voltage ratings, only two current ratings are needed.
Base speed is the speed in revolutions per minute (RPM) for an AC motor operated at rated voltage and frequency when fully loaded. If the motor is operated at less than full load, the output speed will be slightly greater than the base speed.

This motor has a base speed of 1770 RPM at 60 Hz and 1475 RPM at 50 Hz. Because this is a 4-pole motor, its synchronous speed at 60 Hz is 1800 RPM, and its synchronous speed at 50 Hz is 1500 RPM.
Service Factor

Service factor is a number that is multiplied by the rated power of the motor to determine the power at which the motor can be operated for short periods. Therefore, a motor designed to operate at or below its nameplate horsepower rating has a service factor of 1.0.

Some motors are designed for a service factor higher than 1.0, so that they can, at times, exceed their rated horsepower. Keep in mind that any motor operating continuously above its rated horsepower will have a reduced service life.

This motor has a service factor of 1.15 for 60 Hz applications. A 1.15 service factor motor can be operated 15% higher than its nameplate horsepower. Therefore this 5 HP motor can be operated at 3.45 HP.

For 50 Hz applications, this motor has a 1.0 service factor, so it should not be operated above 2.238 kW.

This motor’s service factor is also 1.0 when it is controlled by a variable frequency drive (VFD).
NEMA defines motor insulation classes to describe the ability of motor insulation to handle heat. Four commonly used insulation classes are A, B, F, and H. All four classes identify the allowable temperature rise from an ambient temperature of 40° C (104° F). Ambient temperature is the temperature of the surrounding air.

Temperature rises in the motor windings as soon as the motor is started. The combination of ambient temperature and allowed temperature rise equals the maximum rated winding temperature. If the motor is operated at a higher winding temperature, service life will be reduced.

The accompanying graphic also shows the allowable temperature rise for motors operated at a 1.0 service factor at altitudes no higher than 3300 ft. Each insulation class has a margin allowed to compensate for the motor’s hot spot, a point at the center of the motor’s windings where the temperature is higher. For motors with a service factor of 1.15, add 10° C to the allowed temperature rise for each motor insulation class. The motor in this example has insulation class B and a service factor of 1.15 for 60 Hz applications. This means that its winding temperature is allowed to rise to 130° C with an additional 10° C hot spot allowance.
Motor efficiency is a subject of increasing importance, especially for AC motors. AC motor efficiency is important because AC motors are widely used and account for a significant percentage of the energy used in industrial facilities.

Motor efficiency is the percentage of the energy supplied to the motor that is converted into mechanical energy at the motor's shaft when the motor is continuously operating at full load with the rated voltage applied. Because motor efficiencies can vary among motors of the same design, the NEMA nominal efficiency percentage on the nameplate is representative of the average efficiency for a large number of motors of the same type. The motor in this example has a NEMA nominal efficiency of 90.2%.

NEMA also established a NEMA Premium® energy efficiency motors program that helps users and OEMs select highly efficient motors. Motors that qualify carry the NEMA Premium® logo.

U.S. law now requires the majority of three-phase induction motors used in the U.S. to meet or exceed NEMA Premium efficiency levels.
Siemens SIMOTICS motors provide the rugged performance and long service life you have come to depend on. SIMOTICS CU copper rotor motors deliver exceptional operating efficiencies to further reduce your company’s cost of ownership.
NEMA Motor Designs

NEMA also uses letters (A, B, C, and D) to identify motor designs based on torque characteristics.

NEMA design A is the least common type. NEMA A motors have a speed-torque curve similar to that of a NEMA B motor, but typically have higher starting current. As a result, overcurrent protection devices must be sized to handle the increased current.

The characteristics of NEMA B, C, and D motor designs are discussed in this lesson.
Motors are designed with speed-torque characteristics to match the requirements of common applications. The four standard NEMA motor designs (A, B, C, and D) have different characteristics. This section describes each of these motor designs with emphasis on NEMA design B, the most common three-phase AC induction motor design.

Because motor torque varies with speed, the relationship between speed and torque is often shown in a graph called a speed-torque curve. This curve shows the motor’s torque as a percentage of full-load torque over the motor’s full speed range, shown as a percentage of its synchronous speed.

The accompanying speed-torque curve is for a NEMA B motor. NEMA B motors are general purpose, single speed motors suited for applications that require normal starting and running torque, such as fans, pumps, conveyors, and machine tools.

The accompanying graphic shows the full-load torque calculation for a typical 30 HP NEMA B motor with a full-load speed of 1765 RPM.
Starting torque, also referred to as locked rotor torque, is the torque that the motor develops each time it is started at rated voltage and frequency. When voltage is initially applied to the motor’s stator, there is an instant before the rotor turns. At this instant, a NEMA B motor develops a torque approximately equal to 150% of full-load torque. For the 30 HP, 1765 RPM motor used in this example, that’s equal to 134 lb-ft of torque.

As the motor picks up speed, torque decreases slightly until point B on the graph is reached. The torque available at this point is called pull-up torque. For a NEMA B motor, this is slightly lower than starting torque.

As speed continues to increase from point B to point C, torque increases up to a maximum value at approximately 200% of full-load torque. This maximum value of torque is referred to as breakdown torque. The 30 HP motor in this example has a breakdown torque of 178.6 lb-ft.

Torque decreases rapidly as speed increases beyond breakdown torque until it reaches full-load torque at a speed slightly less than 100% of synchronous speed. Full-load torque is developed with the motor operating at rated voltage, frequency, and load.
Starting Current

Starting current, also referred to as locked rotor current, is the current supplied to the motor when the rated voltage is initially applied with the rotor at rest.

Full-load current is the current supplied to the motor with the rated voltage, frequency, and load applied and the rotor up to speed.

For a standard efficiency NEMA B motor, starting current is typically 600 to 650% of full-load current. Premium efficiency NEMA B motors typically have a higher starting current than standard efficiency NEMA B motors.

Knowledge of the current requirements for a motor is critical for proper application.
NEMA C motors are designed for applications that require a high starting torque for hard to start loads, such as heavily-loaded conveyors, crushers, and mixers.

Despite the high starting torque, these motors have relatively low starting current. Slip and full-load torque are about the same as for a NEMA B motor.

NEMA C motors are typically single speed motors which range in size from approximately 5 to 200 HP.

The accompanying speed-torque curve is for a 30 HP NEMA C motor with a full-load speed of 1765 RPM and a full-load torque of 89.3 lb-ft.

In this example, the motor has a starting torque of 214.3 lb-ft, 240% of full-load torque, and a breakdown torque of 174 lb-ft.
The starting torque of a NEMA design D motor is approximately 280% of the motor’s full-load torque. This makes it appropriate for very hard to start applications such as punch presses and oil well pumps.

NEMA D motors have no true breakdown torque. After starting, torque decreases until full-load torque is reached. Slip for NEMA D motors ranges from 5 to 13%.

The accompanying speed torque curve is for a 30 HP NEMA D motor with a full-load speed of 1656 RPM and a full load torque of 95.1 lb-ft. This motor develops approximately 266.3 lb-ft of starting torque.
Chapter 3 – NEMA Motors

This chapter covers the following topics:

• Motor Designs
• Motor Application
• Motor Enclosures
Voltage Variation

Several factors can affect the performance of an AC motor, and these factors must be considered when applying a motor.

AC motors have a rated voltage and frequency. Some motors have connections for more than one rated voltage. The accompanying table shows the most common voltage ratings for NEMA motors.

<table>
<thead>
<tr>
<th>Standardized Voltages/Frequencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>60 Hz</td>
</tr>
<tr>
<td>115 VAC</td>
</tr>
<tr>
<td>220 VAC</td>
</tr>
<tr>
<td>230 VAC</td>
</tr>
<tr>
<td>460 VAC</td>
</tr>
<tr>
<td>575 VAC</td>
</tr>
</tbody>
</table>

A small variation in supply voltage can have a dramatic affect on motor performance. In the following chart, for example, when voltage is 10% below the rated voltage of the motor, the motor has 20% less starting torque. This reduced voltage may prevent the motor from getting its load started or keeping it running at rated speed.

A 10% increase in supply voltage, on the other hand, increases the starting torque by 20%. This increased torque may cause damage during startup. A conveyor, for example, may lurch forward at startup. A voltage variation also causes similar changes in the motor's starting and full-load currents and temperature rise.
### Additional Derating Factors

A variation in the frequency at which the motor operates causes changes primarily in speed and torque characteristics. A 5% increase in frequency, for example, causes a 5% increase in full-load speed and a 10% decrease in starting torque.

<table>
<thead>
<tr>
<th>Frequency Variation</th>
<th>% Change in Full-Load Speed</th>
<th>% Change in Starting Torque</th>
</tr>
</thead>
<tbody>
<tr>
<td>+5%</td>
<td>+5%</td>
<td>-10%</td>
</tr>
<tr>
<td>-5%</td>
<td>-5%</td>
<td>+11%</td>
</tr>
</tbody>
</table>

Standard motors are designed to operate below 3300 feet. Air is thinner, and heat is not dissipated as quickly above 3300 feet. Most motors must be derated for altitudes above 3300 feet. The accompanying chart shows typical horsepower derating factors, but the derating factor should be checked for each motor. A 50 HP motor operated at 6000 feet, for example, would be derated to 47 HP, providing the 40°C ambient rating is still required.

<table>
<thead>
<tr>
<th>Altitude (in Feet)</th>
<th>Derating Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>3300 to 5000</td>
<td>0.97</td>
</tr>
<tr>
<td>5001 to 6600</td>
<td>0.94</td>
</tr>
<tr>
<td>6601 to 8300</td>
<td>0.90</td>
</tr>
<tr>
<td>8301 to 9900</td>
<td>0.96</td>
</tr>
<tr>
<td>9901 to 11,500</td>
<td>0.82</td>
</tr>
</tbody>
</table>

The ambient temperature may also have to be considered. The ambient temperature requirement may be reduced from 40°C to 30°C at 6600 feet on many motors. However, a motor with a higher insulation class may not require derating in these conditions.
Matching Motors to the Load

One way to evaluate whether the torque capabilities of a motor meet the torque requirements of the load is to compare the motor’s speed-torque curve with the speed-torque requirements of the load.

A table, like one shown in yellow, can be used to find the load torque characteristics. NEMA publication MG 1 is one source of typical torque characteristics.
Calculating Load Torque

The most accurate way to obtain torque characteristics of a given load is from the equipment manufacturer. However, the following procedure illustrates how load torque can be determined. The accompanying illustration shows a pulley fastened to the shaft of a load. A cord is wrapped around the pulley with one end connected to a spring scale. Pull on the scale until the shaft turns and note the force reading on the scale. Then, multiply the force required to turn the shaft by the radius of the pulley to calculate the torque value. Keep in mind that the radius is measured from the center of the shaft.

For example, if the radius of the pulley is 1 foot and the force required to turn the shaft is 10 pounds, the torque requirement is 10 lb-ft. Remember that this is just the required starting torque. The amount of torque required to turn the load can vary with speed.

At any point on the speed-torque curve, the amount of torque produced by a motor must always be at least equal to the torque required by its load. If the motor cannot produce sufficient torque, it will either fail to start the load, stall, or run in an overloaded condition. This will probably cause protective devices to trip and remove the motor from the power source.
In the accompanying example, a centrifugal pump requires a full-load torque of 600 lb-ft. This pump only needs approximately 20% of full-load torque to start. The required torque dips slightly as the load begins to accelerate and then increases to full-load torque as the pump comes up to speed. This is an example of a variable torque load.

The motor selected in this example is a NEMA B motor that is matched to the load. In other words, the motor has sufficient torque to accelerate the load to rated speed.
Screw Down Actuator Example

In this example, the load is a screw down actuator with a starting torque equal to 200% of full-load torque. Note that the NEMA B motor chosen for this example does not provide sufficient torque to start the load.

One solution to this problem is to use a higher horsepower NEMA B motor. A less expensive solution might be to use a NEMA D motor which has higher starting torque for the same horsepower rating.
Volts Per Hertz Ratio

Many applications require the speed of an AC motor to vary. The easiest way to vary the speed of an AC induction motor is to use an AC drive to vary the applied frequency and voltage. Operating a motor at other than the rated frequency and voltage affect both motor current and torque.

The volts per hertz (V/Hz) ratio is the ratio of applied voltage to applied frequency for a motor. 460 VAC is a common voltage rating for an industrial AC motor manufactured for use in the United States. These motors typically have a frequency rating of 60 Hz. This provides a 7.67 V/Hz ratio.

Not every motor has a 7.67 V/Hz ratio. A 230 Volt, 60 Hz motor, for example, has a 3.8 V/Hz ratio. The accompanying graphs illustrate the constant volts per hertz ratio of a 460 volt, 60 Hz motor and a 230 volt, 60 Hz motor operated over the constant torque range.

The V/Hz ratio affects motor flux, magnetizing current, and torque. If the frequency is increased without a corresponding increase in voltage, motor speed increases, but flux, magnetizing current, and torque decrease.

\[
\Phi \propto \frac{E}{F}
\]

Proportional to \( \propto \), Flux = \( \Phi \), Voltage = \( E \), Frequency = \( F \)

\[
T = k\Phi I_w
\]

Torque = \( T \), Motor Constant = \( k \), Working current = \( I_w \)
When a NEMA B motor is started at full voltage, it develops approximately 150% starting torque and a high starting current. When the motor is controlled by an AC drive, the motor is started at reduced voltage and frequency. As the motor is brought up to speed, voltage and frequency are increased, and this has the effect of shifting the motor's speed-torque curve to the right. The dotted lines on the accompanying speed-torque curve represent the portion of the curve not used by the drive. The drive starts and accelerates the motor smoothly as frequency and voltage are gradually increased to the desired speed. This is possible because an AC drive is capable of maintaining a constant volts per hertz ratio from approximately zero speed to base speed, thereby keeping flux constant.

Some applications require higher than 150% starting torque. This is possible if the drive and motor are appropriately sized. Typically drives are capable of producing over 100% of drive nameplate rated current for one minute. The drive must be sized to take into account the higher current requirement.
AC motors operated with constant voltage and frequency have constant flux and therefore constant torque through the normal speed range. An AC drive is capable of operating a motor with constant flux from approximately 0 Hz to the motor’s rated nameplate frequency (60 Hz in this example). This is the constant torque range. The top end of this range is the motor’s base speed. As long as a constant volts per hertz ratio is maintained the motor will have constant torque characteristics.

Some applications require a motor to be operated above base speed, but the applied voltage cannot be increased above the rated value for an extended time. Therefore, as frequency is increased, stator inductive reactance increases and stator current and torque decrease. The region above base speed is referred to as the constant horsepower range because any change in speed is compensated by the opposite change in torque.

If a motor operates in both the constant torque and constant horsepower ranges, constant volts per hertz and torque are maintained up to 60 Hz. Above 60 Hz, the volts per hertz ratio and torque decrease as speed increases.
Continuous and Intermittent Torque Ranges

AC motors operating within rated values can continuously apply load torque. For example, the accompanying graph shows the continuous torque range (in green) for a typical AC motor. The sample motor can be operated continuously at 100% torque up to 60 Hz. Above 60 Hz the V/Hz ratio decreases and the motor cannot develop 100% torque, but can still be operated continuously at 25% torque at 120 Hz.

This sample motor is also capable of operating above rated torque intermittently. The motor can develop as much as 150% torque for starting, accelerating, or load transients, assuming that the associated drive can supply the current. As with the continuous torque range, the amount of torque that can be provided intermittently decreases above base speed.
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This chapter covers the following topics:

• Motor Designs
• Motor Application
• Motor Enclosures
A motor’s enclosure not only holds the motor’s components together, it also protects the internal components from moisture and containments. The degree of protection depends on the enclosure type. In addition, the type of enclosure affects the motor’s cooling. There are two broad categories of enclosures: open and totally enclosed.

Open enclosures permit cooling air to flow through the motor. One type of open enclosure is the open drip proof (ODP) enclosure. This enclosure has vents that allow for air flow. Fan blades attached to the rotor move air through the motor when the rotor is turning. The vents are positioned so that liquids and solids falling from above at angles up to 15° from vertical cannot enter the interior of the motor when the motor is mounted on a horizontal surface.

When the motor is mounted on a vertical surface, such as a wall or panel, a special cover may be needed. ODP enclosures should be used in environments free from contaminants.
Totally Enclosed Non-Ventilated Enclosure

In some applications, the air surrounding the motor contains corrosive or harmful elements which can damage the internal parts of a motor. A totally enclosed non-ventilated (TENV) motor enclosure limits the flow of air into the motor, but is not airtight. However, a seal at the point where the shaft passes through the housing prevents water, dust, and other foreign matter from entering the motor along the shaft.

Most TENV motors are fractional horsepower. However, integral horsepower TENV motors are used for special applications. The absence of ventilating openings means that all the heat from inside the motor must dissipate through the enclosure by conduction. These larger horsepower TENV motors have an enclosure that is heavily ribbed to help dissipate heat more quickly. TENV motors can be used indoors or outdoors.
A totally enclosed fan-cooled (TEFC) motor is similar to a TENV motor, but has an external fan mounted opposite the drive end of the motor. The fan blows air over the motor's exterior for additional cooling.

The fan is covered by a shroud to prevent anyone from touching it. TEFC motors can be used in dirty, moist, or mildly corrosive environments.
An explosion proof (XP) motor is similar in appearance to a TEFC motor, but has a number of features needed for safe operation in hazardous applications, such as those found in chemical processing, mining, foundry, pulp and paper, waste management, and petrochemical industries.

In the U.S., the application of motors in hazardous locations is subject to the National Electrical Code® as well as standards set by Underwriters Laboratories and various regulatory agencies.

Division I locations normally have hazardous materials present in the atmosphere. Division II locations may have hazardous material present in the atmosphere under abnormal conditions.

Locations defined as hazardous, are further defined by the class and group of hazard. For example, Class I, Groups A through D have gases or vapors present. Class II, Groups E, F, and G have flammable dust, such as coke or grain dust. Class III is not divided into groups. This class involves ignitable fibers and lint.
NEMA has standardized motor dimensions for a range of frame sizes. Standardized dimensions include bolt hole size, mounting base dimensions, shaft height, shaft diameter, and shaft length. Use of standardized dimensions allows existing motors to be replaced without reworking the mounting arrangement. In addition, new installations are easier to design because the dimensions are known.

Standardized dimensions include letters to indicate the dimension’s relationship to the motor. For example, the letter C indicates the overall length of the motor and the letter E represents the distance from the center of the shaft to the center of the mounting holes in the feet.

Dimensions are found by referring to a table in the motor data sheet and referencing the letter to find the desired dimension.
NEMA divides standard frame sizes into two categories, fractional horsepower and integral horsepower. The most common frame sizes for fractional horsepower motors are 42, 48, and 56. Integral horsepower motors are designated by frame sizes 143 and above.

A T in the motor frame size designation for an integral horsepower motor indicates that the motor is built to current NEMA frame standards. Motors that have a U in their motor frame size designation, are built to NEMA standards that were in place between 1952 and 1964.

The frame size designation is a code to help identify key frame dimensions. The first two digits are used to determine the shaft height. The shaft height is the distance from the center of the shaft to the mounting surface. To calculate the shaft height, divide the first two digits of the frame size by 4. For example, a 143T frame size motor has a shaft height of 3½ inches (14 ÷ 4).
The third digit in the integral T frame size number is the NEMA code for the distance between the center lines of the motor feet mounting bolt holes.

The distance is determined by matching this digit with a table in NEMA publication MG-1. For example, the distance between the center lines of the mounting bolt holes in the feet of a 143T frame is 4.00 inches.
The typical floor mounting positions are shown in the accompanying graphic, and are referred to as F-1 and F-2 mountings. The conduit box can be located on either side of the frame to match the mounting arrangement and position.

The standard location of the conduit box is on the left-hand side of the motor when viewed from the shaft end. This is referred to as the F-1 mounting. The conduit opening can be placed on any of the four sides of the box by rotating the box in 90° steps.

With modification, a foot-mounted motor can be mounted on a wall and ceiling. Typical wall and ceiling mounts are shown in the accompanying illustration. Wall mounting positions have the prefix W, and ceiling mounted positions have the prefix C.
C-face and D-flange Motor Mounts

Motors are mounted on equipment in various ways. Two common approaches for NEMA motors are C-face and D-flange mounts.

The face, or the end, of a C-face motor has threaded bolt holes. Bolts to mount the motor pass through mating holes in the equipment and into the face of the motor.

The bolts go through the holes in the flange of a D-flange motor and into threaded mating holes of the equipment.
Simulators

Engineered to provide a real-world experience, Siemens simulators are fully functional, ready-to-use systems available in a variety of configurations.

System-level design makes the simulators an invaluable tool for program testing and debugging, reinforcing learning, shop floor troubleshooting, and more. With portable construction and hard-shell cases, they can be easily transported. Custom-built systems are also available.

For additional information: www.usa.siemens.com/sitrain
Chapter 4 – Siemens Motors

This chapter covers the following topics:

- NEMA Motors
- IEC Motors
- Above NEMA Motors
For applications that require more than one base speed, Multi-Speed motors are offered with 1 winding for variable torque.

Siemens inverter duty motors are rated for continuous operation in a 40°C ambient at altitudes up to 3300 feet above sea level. These rugged motors are manufactured for severe duty adjustable speed drive applications such as centrifugal fans, pumps, blowers, mixers, mining, foundry, pulp and paper and petrochemical.

Siemens full range of TEFC Vertical P-Base motors are the right choice for applications such as centrifugal pumps, turbine pumps, cooling towers, mixers, pulp and paper, petrochemical, irrigation, agriculture and waste water treatment.
Siemens GP100A general purpose motors with a precision die cast aluminum frame, bearings, housing, and bolt-on feet have high structural strength as the result of finite element analysis that strategically places material within each component to resist the effects of stress and vibration. GP100A motors weigh less than comparable rolled-steel frame motors, but provide more structural strength for a wider variety of industrial applications. They are ideal in material handling, pump, fan compressors and other industrial applications.

Siemens GP100 general purpose cast iron motors also have high structural strength through the use of finite element analysis to strategically place material within each component to resist the effects of stress and vibration. Materials that resist corrosion are used to ensure a long service life in a wide variety of industrial applications.
Siemens SD100 severe duty motors are ideal for use in chemical processing, mining, foundry, pulp and paper, waste management and petroleum/chemical applications.

They are available with a wide selection of application-matched modifications to meet specific needs, ambient conditions and installation requirements. They are available with NEMA Premium® operational efficiencies as standard or NEMA Premium PLUS efficiencies.

Siemens SD100 IEEE841 motor is the ultimate NEMA design motor. It is designed and manufactured to meet or exceed IEEE Standard 841-2009 requirements for efficiency, performance, construction, adjustable-speed operation and long service life in the most demanding applications.
Explosion Proof Motors

Siemens rugged explosion-proof motors provide reliable operation even under extreme conditions. Siemens XP100 explosion-proof motors are UL listed and CSA certified for gas and dust ignition environments and suitable for Class I, Groups C&D, Class II, Groups F&G, Division I hazardous area classifications. They are also available for drill rig duty: Class I, Group D, Division I hazardous locations.
Chapter 4 – Siemens Motors

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- NEMA Motors
- IEC Motors
- Above NEMA Motors
Siemens manufactures a wide range of motors to International Electrotechnical Commission (IEC) standards. IEC has standardized dimensions for motors, but these dimensions differ from NEMA standards. An example of the IEC dimensions are shown in the accompanying graphic.

Siemens IEC motors fall into the following categories.

- Standard motors (1LE1)
- Standard motors (1LA/1LG)
- Explosion-Proof Motors
- Non-standard frame motors
Different energy efficiency standards exist worldwide for induction motors. To promote international harmonization, the international standard IEC 60034-30-1 03/2014 (Rotating electrical machines – Part 30: Efficiency classes of single-speed, three-phase, cage-induction motors) was created. This groups most 50 Hz low-voltage asynchronous motors into the following international efficiency (IE) classes.

- IE1 (Standard Efficiency)
- IE2 (High Efficiency)
- IE3 (Premium Efficiency)
- IE4 (Super Premium Efficiency)

IE2 for 50 Hz motors corresponds to NEMA High Efficiency for 60 Hz motors.

IE3 for 50 Hz motors corresponds to NEMA Premium Efficiency for 60 Hz motors.
Siemens 1LE1 motors are very compact and employ innovative, state-of-the-art technologies. 1LE1 rotors are manufactured from a combination of highly conductive materials to minimize rotor losses and provide excellent starting and switching behavior.

1LE1 motors with an aluminum frame are suitable for a wide range of standard drive tasks including pump, fan, compressor, conveyor, and lifting equipment applications.

1LE1 motors with a cast iron frame are especially rugged and can be used in the toughest of environments including crusher, mixer, and petrochemical applications.

1LE1 motors have the following additional design features:
- Integrated lifting eye bolts
- Bolt-on mounting feet
- Reinforced bearing end shields
- Terminal boxes are easy to access
- Encoders, brakes, and external fans can be easily added
Standard Motors (1LA, 1LG)

Siemens standard IEC motors are available, across the board in efficiency classes IE2 and IE3 for the area of validity of EU Regulation 640/2009 from 750 Watts up to 375 kW.

These motors are also certified according to EISA for the NAFTA market in the Energy Efficiency and Premium Efficiency classes.

Siemens standard IEC motors are available with either an aluminum frame or a cast iron frame. Examples of Siemens standard IEC motors include 1LA series motors and 1LG series motors.
Areas subject to explosion hazard are divided into zones. Division into zones depends on the chronological and geographical probability of the presence of a hazardous, potentially explosive atmosphere. Information and specifications for classification of the zones are laid down in the following standards:

- IEC/EN 60079-10-1 for gas atmospheres
- IEC/EN 60079-10-2 for dust atmospheres

A further distinction is made among the various explosion groups and temperature classes, and these are included in the hazard assessment for the areas at risk.

Operating equipment must comply with minimum protection requirements for the zones and associated hazards.

Siemens offers a broad range of explosion-protected motors designed to operate reliably even under the most extreme conditions.
Siemens non-standard motors, frame size 315 and above, are available as low-voltage motors with a power range from 200 kW to 4 MW and as high-voltage motors up to over 100 MW. This includes both synchronous and induction motors for all the typical voltages and cooling types.

Included in this category are H-compact series and N-compact series motors that offer optimum efficiency, high power density, and compact designs that result in smaller space requirements and lower weight.
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Chapter 4 – Siemens Motors

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- NEMA Motors
- IEC Motors
- Above NEMA Motors
Motors designed to operate with voltages above 1000 volts are often referred to as high voltage motors. Siemens high voltage motors are collectively marketed under the tradename SIMOTICS HV. This includes the following motor types.

- Asynchronous motors from 150 kW to 38 MW and voltages up to 13.8 kV.
- Asynchronous slip ring motors from 300 kW to 8 MW
- Synchronous motors from 2.1 MW to above 100 MW

Each of these categories can be further divided. For example, SIMOTICS HV asynchronous motors include the following product families.

- Compact motors
- Modular motors
- High power motors
- High torque motors
- Specialized motors
Above NEMA Motors

In the U.S., motors that exceed NEMA standard power ratings are referred to as above NEMA motors. Siemens manufactures a complete line of large AC induction motors at our Norwood, Ohio plant.

The Norwood plant produces horizontal AC induction motors up to 18,000 HP with operating voltages from 460 V to 13.2 kV. The plant also manufactures a complete line of vertical AC induction motors up to 6,000 HP.

Siemens above NEMA motors are available in the categories shown below.

- Specialty motors manufactured to American Petroleum Institute standards API541 or API547
- Horizontal, foot-mounted motors designed to comply with the IEEE 841-2009 standard for the petroleum and chemical industries
- Horizontal and vertical motors with the following enclosure types
  - Open drip proof (ODP)/ weather protected I (WPI)
  - Totally enclosed air-to-air cooled (TEAAC)
  - Totally enclosed fan cooled (TEFC)
  - Totally enclosed water-to-air cooled (TEWAC)
  - Weather protected II (WPII)
Highly demanding process industries from oil production and refining to chemical processing and power generation are the ultimate test of motor reliability. Continuous operation is critical to these industries, and an electrical or mechanical failure of a critical motor means not only lost production time, but lost revenue as well.

The requirements for success in these settings are so crucial that the American Petroleum Institute has adopted two rigorous standards for motor performance: API 541 for critical service motors, and API 547 for severe-duty general purpose motors.

While the two API standards are delineated by horsepower, an even more important differentiator is the criticality of the application. When the motor is critical to the reliable operation of a process, engineering to the API 541 standard, even when the horsepower requirements would allow an API 547 motor, is the clear choice.

For general purpose applications that are non-critical but still require a severe-duty motor, the API 547 specification typically offers a less expensive alternative.
For more than 100 years, Siemens has provided the solutions the pulp and paper industry needs for high performance and long service life.

Siemens TEFC motor designs with horsepower ratings up to 3,000 HP provide a low-profile, low maintenance basic solution for the toughest applications.

Motors are available with the features needed to match applications from grinders, barking drums, bleaching, filters, and deflakers, to refiners, beating lines, pulp pumps, press section, and coilers.
H-compact PLUS Motors

H-compact PLUS motors with power ratings up to 18,000 HP (13 MW) and shaft heights up to 710mm are distinguished by their reliability, low maintenance, and efficiency.

H-compact PLUS motors provide outstanding value and have performance and features designed to meet requirements of the most demanding applications.

- High-conductive copper bar rotors and stator windings provide optimal electrical performance.
- Innovative cooling concepts and modular design result in maximized efficiency levels and output and a system that can be integrated into any plant environment.
- Low-windage design and precision within all rotating and stationary components minimize friction losses.
- Distinctive sleeve bearing design provides premium performance and long life.
- High-power density and compact construction meet low space and weight requirements.
- Low noise fulfills health and safety requirements.
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This course covered the following topics:

Chapter 1 - Introduction
  • Basic Concepts

Chapter 2 – Motor Basics
  • Electromagnetism
  • Rotor Rotation

Chapter 3 – NEMA Motors
  • Motor Designs
  • Motor Enclosures

Chapter 4 – Siemens Motors
  • NEMA Motors
  • IEC Motors
  • Above NEMA Motors

This course has covered the topics shown on the left. Thank you for your efforts. You can complete this course by taking the final exam and scoring at least 70%.