Introduction to AC Drives

Table of Contents

Introduction to AC Drives

This module, "Introduction to AC Drives," is designed to familiarize the participant with AC motor theory, AC drive theory, Square D AC drive products and their enclosures, and provide job aids for assisting customers.

Prerequisites

Module 1 - Fundamentals of Electricity - The first module introduces some important concepts that need to be understood in order to effectively learn the material in " Introduction to AC Drives."

Module 2 - Introduction to Distribution Equipment - This module deals with products such as: NEMA enclosures, Digest overview, and circuit breakers.

Module 3 - Introduction to Control Products - You should review the following chapters before proceeding with this course if you feel uneasy about their content:

- **Chapter 1** - Overview of Motor Control

and/or

You are strongly encouraged to complete the AC Motor Theory Course (AUTM 100) which is available on either CD ROM or 3 1/2" disk. This program provides an in-depth coverage of AC motor theory which is necessary in order to understand the relationship between the motor and the AC drive which controls it.

Training Program Components

There are five chapters, including an appendix and glossary, in this course. They are:

- **Chapter 1 - Introduction to AC Motors** - This chapter provides an overview of the components of an AC motor, how the motor operates and AC motor terms and concepts.
- **Chapter 2 - AC Drive Fundamentals** - This chapter covers:
  - Advantages of AC drives over other methods of motor control
  - Applications for AC drives
  - AC drive theory
  - Load and braking considerations
- **Chapter 3 - Square D AC Drive Products** - This chapter covers the features and benefits of the Altivar 16, 66, 56, and 18 AC drive products. The Omegapak 8803 and 8804 products are also covered.
- **Chapter 4 - AC Drive Enclosure Characteristics/Types** - This chapter discusses the different types and characteristics of enclosures available for Square D drive products.
- **Chapter 5 - Helping Customers** - This chapter provides the participant with job aids for dealing with customer drive questions.

- **Glossary of Terms** - This glossary contains the meanings of many terms common to AC drives.

Each chapter in the student workbook includes learning objectives,

Self-Check Questions and Self-Check Answers have been included within each chapter. They will enable you to check your understanding of the material presented to you.

How to Use the Student Workbook

The student workbook provides a self-study training process that is designed to help you learn with or without assistance from a trainer. You will find this workbook becomes a valuable reference tool after you have completed the training, so keep it handy. For the most effective use of this training process, follow the steps on the next page.

Steps to Complete Introduction to AC Drives

1.
Complete the **Self Assessment Study Guide**, if required, and review the answers with those in the back of this workbook.*

2.
For each chapter you want to review, read through the chapter in the workbook. Feel free to take notes or highlight in your workbook.

3.
Complete the **Self Check Test** and review the answers.

4.
Repeat steps 2 - 3 until you complete the training program. Then go to step 5.

5.
Complete the Final Test for Introduction to AC Drives

6.
Call 1-800-832-4593 to complete the testing process *

***** This will help you determine if you already understand the concepts taught in a particular section. If you are more experienced, you may find the results of the Self Assessment Study Guide indicate you should skip some or all the sections and move straight to the Final Test.

SELF ASSESSMENT
STUDY GUIDE

SELF ASSESSMENT STUDY GUIDE

Select the best answer:

1. The armature of a motor consists of ____ .

- **A.** the housing and rotor
- **B.** the shaft and stator
- **C.** the stator and housing
- **D.** the shaft and rotor

2. The magnetic fields of the stator and rotor are changed according to the ___ .

- **A.** the current applied to the motor
- **B.** frequency of the AC voltage applied to the motor
- **C.** the frequency of the current applied to the motor
- **D.** the wattage applied to the motor

3. The speed of the rotor is determined by the ___ .

- **A.** the current applied to the motor
- **B.** frequency of the AC voltage applied to the motor
- **C.** the frequency of the current applied to the motor
- **D.** the wattage applied to the motor

4. The difference between a motor's synchronous and actual rotor speed is called: _____ .

- **A.** Variable torque
- **B.** Dynamic speed
- **C.** Slip
- **D.** Magnetic flux

5. The torque a motor produces is directly related to ____ .

- **A.** the current applied to the motor
- **B.** frequency of the AC voltage applied to the motor
- **C.** the frequency of the current applied to the motor
- **D.** the wattage applied to the motor

6. The maximum torque that a motor can produce is called: _____ .

- **A.** Full load torque
- **B.** Constant torque
- **C.** Breakdown torque
- **D.** Overload toque

7. A motor's service factor indicates the: _____ .

- **A.** Approximate life expectancy of the motor if applied within the rated nameplate parameters
- **B.** The NEMA rating of the motor which is comparable to the torque performance of the motor.
- **C.** Electrical power supplied to the motor.
- **D.** Overloads which may be carried by the motor without exceeding the maximum temperature recommended for the insulation

8. Match the components of an AC drive with their function:

___ Inverter	**A.** This section smoothes rectified DC before it goes to the next section.
___ DC bus filtering	**B.** This section changes DC into an adjustable frequency synthetic AC
___ Converter	**C.** This section changes 60 Hz AC power into DC

9. The difference between a soft start and an AC drive is: _____ .

- **A.** That the soft start reduces voltage and current at startup
- **B.** That an AC drive controls motor startup by reducing startup torque.
- **C.** That a soft start can be used in place of an AC drive
- **D.** All of the above
- **E.** None of the above

10. Maintaining the volts per Hertz ratio is necessary because: _____ .

- **A.** In order to accurately measure a given motor's speed then the ratio of both the voltage and frequency must be maintained.
- **B.** When a motor is running at less than full speed maintaining this ratio provides a method of keeping the magnetic flux constant, thus producing full load-torque.
- **C.** The voltage and frequency coming from the power generating station may varies in both voltage and frequency.
- **D.** The horsepower of the motor is dependent upon this ratio.

11. With a constant torque load: _____ .

- **A.** Torque remains the same as the speed changes.
- **B.** Horsepower varies inversely with the speed.
- **C.** Torque remains the same as the current changes.
- **D.** All of the above.

12.__________ AC drives can only be ordered as replacements to existing equipment.

- **A.** ALTIVAR
- **B.** OMEGAPAK
- **C.** ALTIVAR and OMEGAPAK
- **D.** There are no limited offerings with AC drives

13. The complete ALTIVAR family consists of _______ .

- **A.** ALTIVAR 16, 26, 55, and 67
- **B.** ALTIVAR 8803, 8804, 16, and 18
- **C.** ALTIVAR 8803 and 8804
- **D.** ALTIVAR 16, 18, 56, and 66

14. The ALTIVAR drives meet _______ standards.

- **A.** ISO 9000 series, and UL, CSA, IEC, VDE
- **B.** UL, CSA, IEC, VDE
- **C.** ISO 9000, ISO 3000 series, and UL, VDE
- **D.** ISO 9007 series, and UL, CSS, ICC, VDE

15. _______ are the major components for Dynamic Braking.

- **A.** Jumper J-12 to switch a resistor circuit in and out, and a separately mounted brake
- **B.** A separately mounted semi-conductor circuit and resistor R-7
- **C.** A power semi-conductor to switch resistor circuit in and out, and a separately mounted braking resistor
- **D.** A power semi-conductor to switch resistor circuit in and out, and three separately mounted braking resistors

16. An open type drive is bought as _____.

- **A.** As a component piece
- **B.** As a total Square D enclosure
- **C.** As a total Square D MCC
- **D.** All of the above

17. _____ drive(s) can be used for open type applications.

- **A.** OMEGAPAK 8803 and 8804
- **B.** ALTIVAR 16, 18
- **C.** ALTIVAR 16, 18, 56, and 66
- **D.** ALTIVAR 16, 18, 56, 66, and OMEGAPAK 8803 and 8804

18. Enclosed type drives are manufactured at the _____.

- **A.** Square D Raleigh plant in North Carolina
- **B.** Square D Columbia plant in South Carolina
- **C.** Square D Seneca plant in South Carolina
- **D.** Square D Oxford plant in Ohio

19. _____ drive(s) can be used for MCC applications.

- **A.** OMEGAPAK 8803
- **B.** ALTIVAR 66
- **C.** ALTIVAR 16
- **D.** ALTIVAR 56

20. The MCC drive packages can be from _____.

- **A.** 1-50HP, 220V constant/variable torque or 1-25HP, 480V variable torque low noise
- **B.** 1-800HP, 240V constant/variable torque or 1-75HP, 400V variable torque high noise
- **C.** 1-50HP, 480V constant/variable torque or 1-250HP, 480V variable torque no noise
- **D.** 1-200HP, 480V constant/variable torque or 1-75HP, 480V variable torque low noise

21. Enclosed Type drives are offered in _____.

- **A.** NEMA Type 1 and Type 12 enclosures
- **B.** NEMA Type 1, Type 3, and Type 12 enclosures
- **C.** NEMA Type 12 enclosures
- **D.** NEMA Type 4 and Type 12 enclosures

TURN TO APPENDIX A FOR ANSWERS

Chapter 1 - AC Motor Fundamentals

LEARNING OBJECTIVES

The participant will:

- Be able to identify the components of an AC motor
- Understand how an AC motor operates
- Understand AC motor terms and concepts
- Identify meaning of motor nameplate terms

PREREQUISITES

AC drives control AC motors. It's that simple. So, in order to understand what AC drives are, how they work and where they are applied, you need to first understand the parts of an AC motor and how AC motors function. If you are unsure about AC motor theory here are few suggestions on where you can go to get that information:

- If you are enrolled in Square D Technical Institute, then motor theory was covered in Module 3. You may want to review that module before continuing on with this course.

- For a more in-depth coverage of AC motors (whether or not you are part of Square D Technical Institute or not) you'll find that Square D has available an excellent self paced course on AC Motor Theory - Course # AUTM 100. It is highly recommended that you complete this course prior to starting this course on AC drives. AUTM 100 is available on either 3 1/2" disks or a CD ROM.

While we will present a brief review of AC motor theory and terminology, it is assumed that you meet one or more of the above prerequisites and have a clear understanding of AC motors.

REVIEW OF AC MOTOR THEORY

Some of the reasons you need to understand AC motor theory in order to understand AC drives are:

- To provide customer satisfaction
  - The AC drive and the AC motor work together as a system

- To select the correct drive
  - Must have knowledge of NEMA A, B, C, and D motor speed and torque characteristics

- To ensure desired motor performance
  - Because an AC drive effects:
    - Speed, torque, current, voltage, heating and horsepower

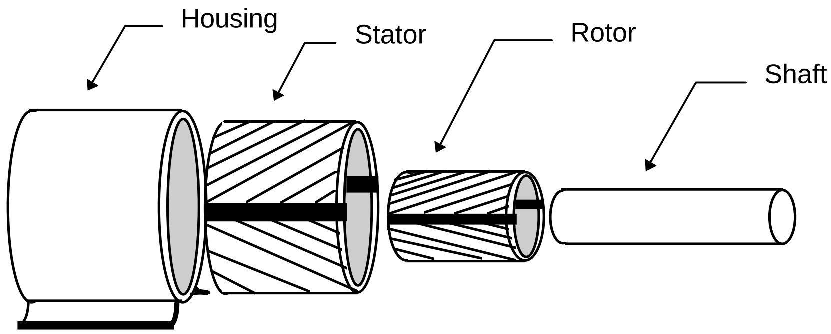
We all know that there is a relationship between a motor, a machine and motor control. The machine does the actual work. The motor is the device which causes the machine to operate. And, the motor controller is the intelligence that directs the motor. That is, it determines when and in what direction the motor will operate. And, it may provide protection for the motor, branch circuits and the operator.

Did you know that the average household has more than 25 electric motors. A medium sized manufacturing plant, such as the Square D plant in Raleigh, NC may have from 4,000 to 5,000 electric motors. And a large automated plant, like an automobile assembly plant could have 25,000 electric motors in it.

And now, let's get on with learning about the fundamentals of AC motors.

AC MOTOR FUNDAMENTALS

Components Of An Electric Motor



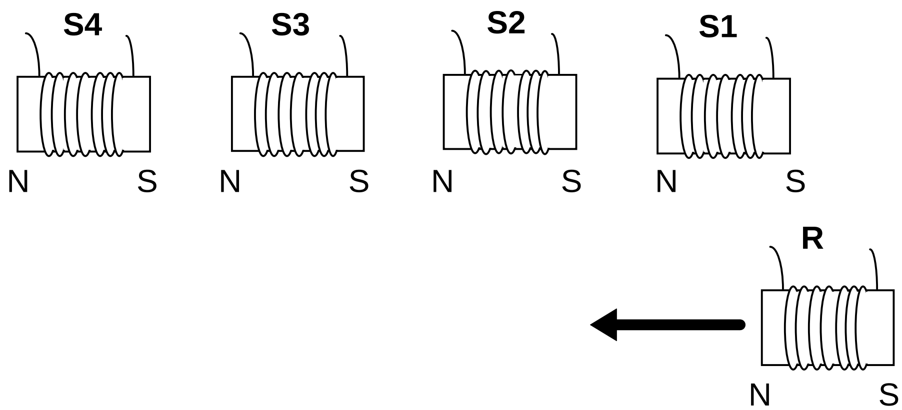
Electric motors are really quite simple. There are only **four basic parts** to an electric motor:

- There is the **housing or external case** that surrounds the other components.
- Mounted inside the housing is the **stator**. The stator is the stationary or non-moving part of the motor's interior. It is made up of wire windings. The moving parts of the motor are the rotor and the shaft.
- The **rotor**, like the stator, also has windings.
- The rotor is connected to the fourth component, the **shaft**. The shaft is a metal rod held in position within the stator by bearings connected to the case. The bearings allow the shaft to rotate inside the stator. The rotor and shaft are often referred to as the armature of the motor.

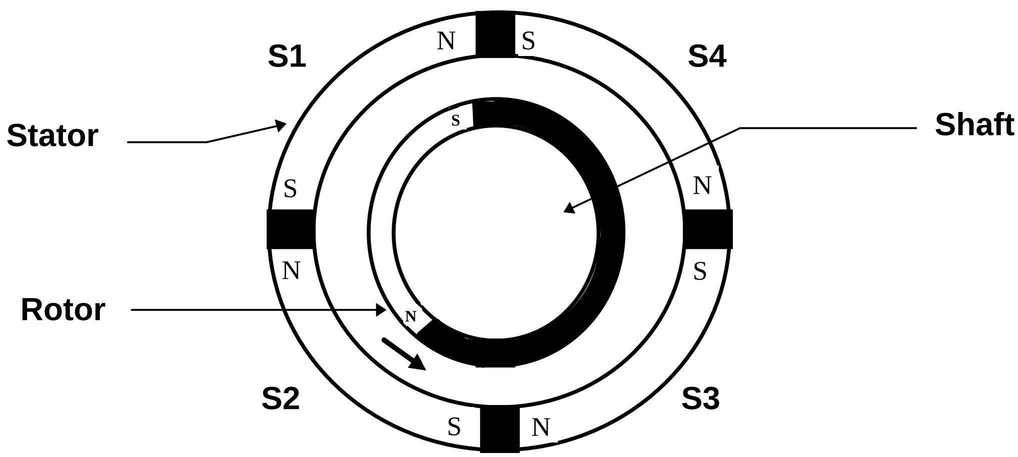
How An Electric Motor Operates

The electric motor operates by converting electrical energy into mechanical energy. Let's represent the motor's stator as an iron block "S" and the rotor as an iron block "R". Both of these iron blocks are wrapped with wire coils. When electrical current is passed through the wire coils, an electromagnetic field is created and the iron blocks become magnetized. All magnets have a North and a South pole. A North pole is always trying to get next to a South pole and visa versa. Two North or two South poles will push away or repel each other. In other words, opposite poles attract and like poles repel. It's this magnetic pull and push principle that makes an electric motor operate.

Suppose that "S" is fastened such that it cannot move. On the other hand, "R" is allowed to move freely. When electricity is passed through the coils and the blocks are magnetized, the opposite poles try to pull together. Block "R" will move towards block "S." If the blocks get together the movement will stop. What if block "S" were mounted in such a way that block "R" couldn't contact it? Block "R" would move until it's positive pole were as close as it could get to block "S" and then motion would stop.



Let's add more "S" blocks (S1, S2, S3, and S4). If S1 were demagnetized just as "R" reached it, and S2 is magnetized, "R" would continue moving toward "S2." If this same process of demagnetizing and magnetizing S1, then S2, then S3 and finally S4, were continued then block "R" would be moving all the time until it reached S4.



In an electric motor the "S" magnets are formed in a circle and the "R" magnet is placed inside this circle and is attached to a shaft. The stator and rotor are magnetized as current flows through the coil windings. The rotor moves so that the opposite poles of the windings can try to move closer to the stator magnets. Just as the magnets are close the magnetic field moves on in the stator, and the rotor chases after it. Since the rotor and shaft are fastened together, the shaft moves. The rotation of the shaft is the mechanical energy created by the conversion of the electrical energy by the motor.

To summarize, the rotor "chases after" the changing magnetic field of the stator which causes the rotor and shaft to rotate. The magnetic fields of the stator and rotor are changed according to the frequency of the AC voltage applied to the motor. Changing the frequency of the voltage applied will alter the speed at which the stator's magnetic fields change. This will, in turn, change the speed of the rotor. Changing the current will alter the strength of the magnetic fields of the rotor and stator. The stronger the magnetic fields the greater the turning force applied by the rotor to the shaft. This twisting or turning force is called torque.

Types of AC Motors

The four principle types of motors (not including single phase types) found in commercial and industrial applications are: squirrel cage induction, wound rotor induction, synchronous, and direct current (dc).

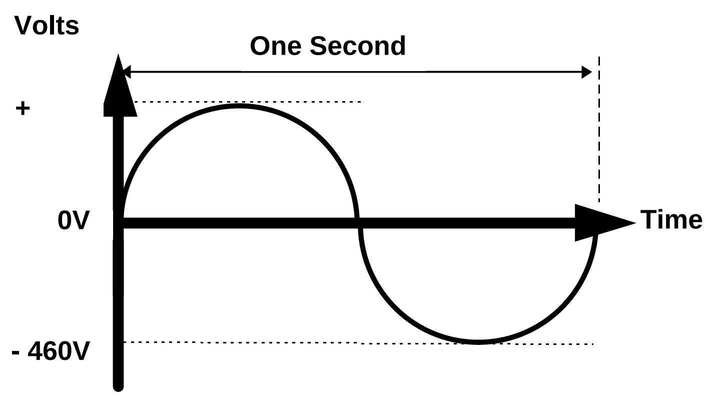
The squirrel cage induction motor is by far the most widely used motor because of its low cost and proven reliability. The wound-rotor induction motor has been used in applications that require high starting torque, controlled starting torque, or speed control. The synchronous separately excited motor has been used in high-horsepower applications where it is advantageous to overexcite the motor to provide power factor correction in an industrial facility. The synchronous permanent magnet and reluctance motor is used in applications that need precise speed for a number of motors operating in combination.

But the squirrel cage motor is by far the simplest, most reliable, least expensive, most readily available and easiest to maintain. In addition, with improvements in AC drives, squirrel cage motors are now applied in the majority of the applications your customers are involved with.

MOTOR TERMS AND CONCEPTS

Motor Terms and Concepts

- **Electric service** is a term used to describe or define electrical power supplied to a motor. The selection of motor control products depends upon the information that is included as part of electrical service. This information includes:
  - **Current** - the current used by the motor is either AC or DC. Square D currently only makes drives for AC motors.
  - **Phase** - a motor can be powered by either single or polyphase electric power. The term polyphase means more than one phase and typically refers to 3 phase.
  - **Frequency** - is the number of electrical pulses that are transmitted over a given period of time. Frequency is measured in hertz (Hz) or cycles per second (cps).



In this example, you see that the voltage builds from zero, in the positive direction up to a peak positive value of + 460 V. Then it starts to decline in value until it reaches zero volts again. Next the voltage starts in the negative direction until it reaches a peak value of
- 460 V. Finally the voltage starts to move back in the positive direction until it reaches zero volts. The change in voltage from zero to a peak positive value, back to zero, to a peak negative value and back to zero is called 1 cycle. It has taken time for a cycle to occur. In our example, that time is one second. Frequency is measured in terms of

cycles per second and the frequency of this example is one cycle per second. The more common term for frequency is called Hertz. One Hertz equals one cycle per second.

Alternating current completes these cycles very rapidly and the number of cycles per second is known as the **frequency**. Throughout the United States AC current typically goes through a cycle 60 times per second, so the frequency is 60 Hertz. In many foreign countries, the AC current cycles 50 times per second, so the frequency is 50 Hertz.

– **Voltage -** electric motors are designed to operate using a specific voltage. Motor control devices are also rated according to the voltage that can be applied to them.

- **Locked rotor current** (LRC) is the current flow required by a motor in order for the motor to start. Locked rotor current may be called Locked rotor amps (LRA).

- **Full Load Amps (FLA**) - this is the current flow required by a motor during normal operation to produce its designed HP. Full load amps (FLA) is also called Full Load Current or (FLC).

- **Speed** (in revolutions per minute), **Torque** (ft.lbs.) and **Horsepower** (HP) are all terms that are used to define motor performance:

  Let's start with **Horsepower**. Motors and engines are measured in horsepower. Horsepower is a standard unit of power which is used to measure the rate at which work is done. One Horsepower is the equivalent of 550 foot-pounds per second --- that is the ability to lift 550 pounds one foot in one second. For example, if an electric motor can lift 550 pounds 10 feet and it takes 10 seconds, then the motor has a horsepower rating of 1 hp.

  In any electric motor the motor torque can be multiplied by the motor speed and the product divided by 5250 (a constant) to determine the rated horsepower.

$$\text{HP} = \frac{\text{Torque (ft.lbs.)} \ \mathbf{X} \ \text{Speed (RPM)}}{5250}$$

  Before continuing the discussion about the horsepower equation, let's look at **torque**.

  Torque is formally defined as: "the force tending to rotate an object, multiplied by the perpendicular radius arm through which the force acts." In the case of a motor, torque is the force which acts on the shaft and causes rotation. Remember that **the amount of torque created is directly related to the amount of current applied to the motor.** The greater the current the stronger the magnetic fields of the stator and rotor, and therefore the greater the turning force of the shaft. A motor is a dumb device. As the load is increased on the shaft, the motor will draw more current (to increase the torque) to try and keep the load moving. If the load were to continue to be increased, the motor will literally destroy itself trying to create the necessary torque to move the load.

  Consider how a motor generates torque vs how it generates **Speed**. Motor speed is measured in rpm (the revolutions per minute the rotor turns) and is the speed at which the rotor rotates inside the stator. This **rotational speed will depend upon the frequency of the AC voltage applied and the number of stator poles**. If the motor has no load, this speed will approach the synchronous speed of the stator field.

- **Synchronous speed** is the speed of an AC induction motor's rotating magnetic field. It is determined by the frequency applied to the stator and the number of magnetic poles present in each phase of the stator windings. This can be expressed by the formula:

$$\text{Synchronous Speed} = \frac{120 \ \mathbf{X} \ \text{Frequency}}{\text{Number of Poles}}$$

For example:

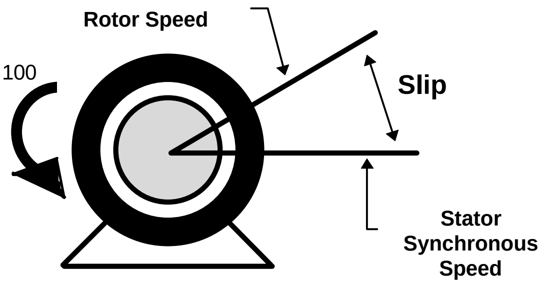
$$\text{Synchronous Speed} = \frac{120 \ \mathbf{X} \ 60 \text{ Hz}}{4 \text{ pole motor}} \qquad = 1800 \text{ rpm}$$

- **Motor Slip**

$$\text{Slip} = \frac{\text{Synchronous Speed} - \text{Rotor Speed}}{\text{Synchronous Speed}} \ \mathbf{X} \ 100$$

$$\frac{1800 \text{ rpm} - 1750 \text{ rpm}}{1800 \text{ rpm}} \ \mathbf{X} \ 100$$

Slip = 2.78%



Slip is the difference between the rotating magnetic field speed in the stator and the rotor speed in AC induction motors. This is usually expressed as a percentage of synchronous speed. If the rotor were rotating at exactly the same speed as the stator's rotating magnetic field (for example, 1800 rpm) then no lines of magnetic force would be cut, no voltage would be generated in the rotor and no current would be present. However, if the rotor slows down by 50 rpm it would now be running at 1750 rpm vs 1800 rpm of the stator field. The rotor bars are now cutting the rotating field at a 50 rpm rate. Now voltage and current would be generated in the rotor, with a resulting magnetic flux pattern. The interaction of these magnetic fields would produce torque. The difference between the synchronous and actual rotor speeds is called slip.

- **Torque vs Speed Relationship:**

Torque, remember is a force exerted on the motor's shaft when a load is added to the rotor. The tendency is for the rotor to slow down, which will create more slip (difference between the stator magnetic field speed and rotor speed), thus creating more torque within the motor.

As the load is increased, the rotor will continue to slow down, which would result in even greater slip as the rotor lags behind the synchronous speed of the rotor. The increased resistance to rotation increases the slip and therefore increases the torque.

Now, lets go back to the horsepower equation again.

$$\text{HP} = \frac{\text{Torque (ft.lbs.) } \mathbf{X} \text{ Speed (RPM)}}{5250}$$

This formula will help you select the proper motor for a job. Notice the **relationship between torque and speed.** It is obvious that a 5 hp motor, designed to run at high speed, will have very little torque. To maintain the equation, torque must decrease as speed increases:

$$\text{HP} = \frac{\text{Torque (ft.lbs.) } \mathbf{X} \text{ Speed (RPM)}}{5250}$$

Conversely, a 5 hp motor with high torque must run at a slow speed.

$$\text{HP} = \frac{\text{Torque (ft.lbs.) } \mathbf{X} \text{ Speed (RPM)}}{5250}$$

An important relationship for you to remember is that:

SPEED IS RELATED TO FREQUENCY
and
TORQUE IS RELATED TO CURRENT

You've already seen that increasing the frequency at which the magnetic fields change will cause an increase in the speed of rotor and shaft rotation. If the frequency were decreased, the motor speed would slow down.

If the current drawn by the stator and rotor is increased, this would cause a strengthening of the magnetic fields. This, in turn, would cause the torque generated by the motor to increase. Likewise, if the current were decreased, the torque would be decreased as well.

In fact the horsepower formula can also be expressed in electrical terms of voltage and current, as:

$$\text{HP (Output)} = \frac{\text{Volts } \mathbf{X} \text{ Amps } \mathbf{X} \text{ 1.732 } \mathbf{X} \text{ Power Factor } \mathbf{X} \text{ Efficiency}}{746}$$

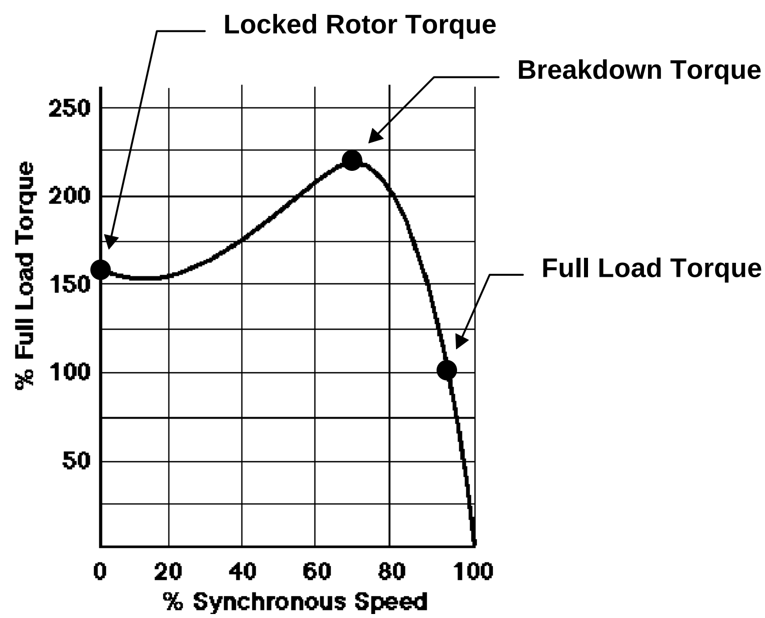
- **Constant and Variable Torque**

If you look at a motor's usage based on the torque requirements of an application, you will find that you may need constant torque or variable torque. One application might require <u>normal</u> starting torque and a <u>normal</u> running torque, for example, a drill machine. This category requires that a motor starts with a normal amount of torque and then continues to run at the required speed.

Another application category might require a <u>high</u> starting torque but a <u>normal</u> running torque. For example, a conveyor that is first loaded up and then started. When the loaded conveyor is started the motor must provide a big push of torque to get the conveyor and its load moving. Once moving, inertia has been overcome and the resistance of friction falls, therefore normal running torque provides adequate power to keep the conveyor running.

The third torque category would be an application that requires a <u>very high</u> starting torque, and a <u>normal</u> running torque.

Starting and running torque can be plotted. As the starting torque increases, motor speed decreases --- remember the equation: speed times torque equals horsepower. As torque increases, the motor speed decreases.



Notice that at zero speed the starting torque is very high. This is needed to get the load moving from a dead stop. As the speed increases the torque curve fluctuates until the full load torque and full load speed are reached.

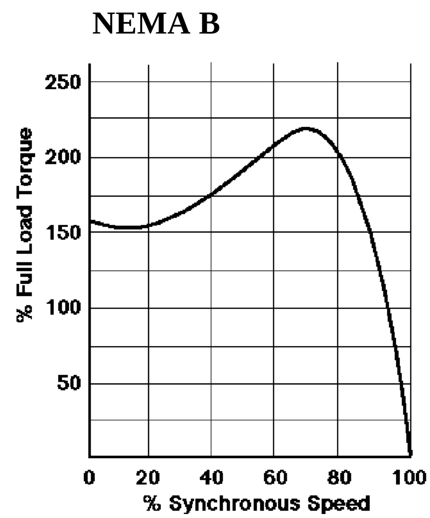
- The **breakdown torque** is the maximum torque that a motor can produce. Higher torque requirements will slow motor speed to a stop. Breakdown torque is the point where speed stops as torque requirement increases.

- **Full load torque** is the amount of torque developed by the motor at rated speed and rated current. The rated speed and current values can be found on the motor nameplate.

- **NEMA Design Ratings**

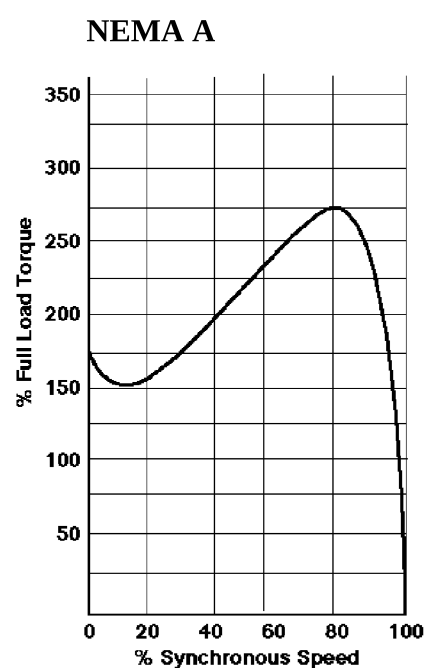
The NEMA ratings refer to torque ratings. These rating apply to motors which are started across the line.

The design areas of the nameplate refer to the NEMA rating of the motor which is comparable to the torque performance of the motor. NEMA has five design ratings of AC induction motors. Each of these designs has a different characteristic for starting current, locked rotor current, breakaway torque, and slip. These designs are NEMA A, B, C, D, and E. Each has a distinct speed vs torque relationship and different values of slip and starting torque.
The most common is the **NEMA Design B** motor.



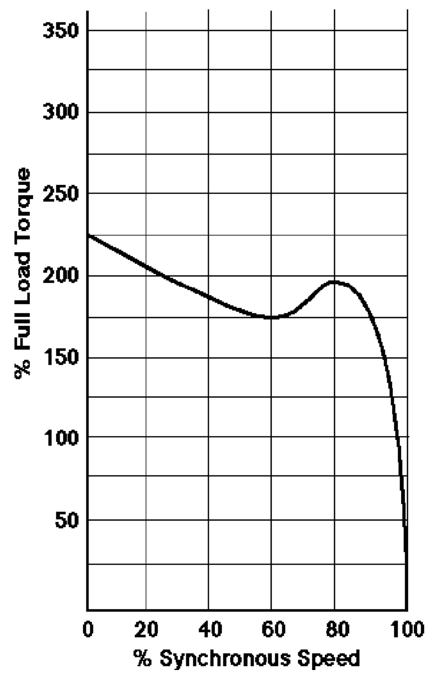
The NEMA B motor's percentage of slip ranges from 2 to 4%. It has medium values for starting or locked rotor torque, and a high value of breakdown torque. This type of motor is very common in fan, pump, light duty compressors, various conveyors, and some light duty machines. The NEMA B motor is an excellent choice for variable torque applications.

The NEMA A motor is similar in many ways to the NEMA B motor. It typically has a higher value of locked rotor torque and its slip can be higher



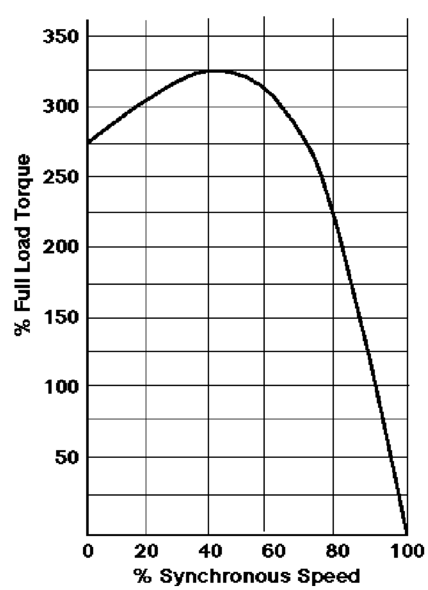
NEMA C motors are well suited to starting high-inertia loads. This is because they have high locked rotor torque capability. Their slip is around 5%, and their starting current requirement is average.

NEMA C



The NEMA D motor is found in heavy duty, high-inertia applications. It has high values of slip (up to 8%), and very high locked rotor torque capability. Typical applications include punch presses, shearing machinery, cranes, and hoists.

NEMA D



- **Motor Load** - a motor provides the conversion of electrical energy to mechanical energy that enables a machine to do work. The energy that a machine requires from a motor is known as the motor load. For example, the motor in a clothes dryer turns the dryer drum. The energy required by the dryer motor to turn the drum is called the dryer's motor load.

- **Motor Overload** - An electric motor for all its other fine qualities has no intelligence and will literally work itself to death. If there is a heavy load on a motor, say when the clothes dryer is full of clothes, the motor will try to produce whatever torque is needed to keep the dryer drum turning. Because the motor load may be increased above normal, a motor overload condition exists. More torque is required from the motor to turn the drum, so the motor draws more current to produce more energy. The higher than normal current flow, which is above the FLC, increases the temperature in the dryer motor. The electric motor could be damaged when the temperature rises above its designed limit.

- **Motor Cooling -** Whenever electrical current is passed through an electrical motor there is a buildup of heat. The amount of heat produced is a function of the work, or loading, done by the motor; the type of electrical signal being sent to the motor; and the eventual changes due to bearing wear and friction. Whenever AC drives are used to control motors it means that the speed of the motor is going to be changed. And, depending upon motor loading, special attention needs to be given to how the motor is going to be cooled. Generally speaking, less speed means less cooling.

  Different motor cooling designs are available:

  - Many motors are sized for a particular application, or horsepower rating, so that the heat produced from the current can be accepted and dissipated by the metal content of the motor. Normal convection and radiation dissipate the heat with the aid on an internal mixing fan. These motors are classified as **"open drip-proof" or "totally enclosed nonventilated (TENV)**."

  - Other electric motors incorporate a fan blade that rotates at the same speed as the motor shaft. This fan blows air across the outside of the motor, cooling it as it runs. However, if an AC drive is used, the lower in speed the motor is made to run, the slower the cooling fan will run also. This can result in a buildup of heat in the motor. These motors are called **"totally enclosed fan-cooled (TEFC)."**

  - Some types of motors use elaborate means for cooling. These are called **"totally enclosed water-to-air cooled," "totally enclosed air over," and "totally enclosed unit cooled."** Obviously, the more complex the cooling method, the more expensive the actual motor will be.

  There are a couple of different strategies used for selecting a motor that will be adequately cooled during operation:

  - One approach is to size the motor with a service factor. A service factor of 1.15 means that the motor has 15% more capacity when operating conditions are normal for voltage, frequency, and ambient temperature. This 15% extra capacity means that the motor is built and sized when the duty cycle is severe, or the loading and speed range is moderate.

  - Another strategy is to simply go up in horsepower, which is how motors are sized. This might put a motor into a larger frame designation, thereby making it weigh more and allowing it to handle a greater amount of heat.

The concern of both of these strategies is that you could end up with a motor that is well oversized for the application. This would cause wasted energy and increase the cost of the motor. Another answer might be to add auxiliary cooling equipment to the motor.

MOTOR NAMEPLATE DATA

Motor Nameplate Data

Squirrel cage motors, like any other type of electrical equipment, require proper application for successful operation. Understanding the nameplate information, which identifies the motor's important features and characteristics, will aid considerably in proper application.

A nameplate is attached to each AC motor and includes information such as:

- Full load speed
- Torque ratings
- Type of enclosure
- Type of insulation
- Temperature Rise Rating
- Service Factor
- Time Rating
- Locked Rotor KVA

- **Frame sizes - I**n 1972 NEMA Standards included numbers for various frame sizes that range from 140 to 680. These are commonly called "T" frame motors. There is a relation between the numbers assigned and their frame dimensions. For example, the first two digits of the number equal four times the dimension in inches from the center line of the shaft to the bottom of the feet. A series of letters is used immediately following the frame size number to help identify certain features.

  The motor nameplate identifies a frame size number and letter which are indicative of dimensions and some features. NEMA has specified certain dimensions for motor frame sizes -- up to 200 hp. These are identified by the numbers listed below.

Frame Number Series

140	220	400
160	250	440
180	280	500
200	320	580
210	360	680

The physical size and consequently the cost of a squirrel cage motor is determined by its frame size. The actual horsepower rating for each frame size will vary and will be determined by several design parameters, which have been standardized by NEMA. Above approximately 200 hp, electrical standards apply for motors, but the frame sizes are not standardized.

- **Full Load Speed** - The motor nameplate identifies the rated full load speed. This speed is one of the key considerations in determining the motor horsepower required for a given load. The motor synchronous speed is influenced by the number of magnetic poles in the stator.

The synchronous speed is slightly higher than the motor shaft speed. As the number of poles in a motor design is increased, the rated synchronous speed is decreased per the formula:

$$\text{Synchronous Speed} = \frac{120 \ \mathbf{X} \ \text{Frequency}}{\text{Number of Poles}}$$

Because of this the physical size of a squirrel cage motor is inversely related to its speed --- meaning, the frame size may be larger as the rated synchronous speed becomes lower. For example, a 100 hp, 600 rpm twelve pole motor will be considerably larger than a 100 hp, 3600 rpm two pole motor.

- **Torque Ratings** - The motor nameplate identifies the type of design motor (A, B, C, D, E), which is indicative of its locked rotor and peak torque ratings. In addition the nameplate identifies the rated horsepower at rated speed and from this information, rated full load torque can be determined. The full load torque rating will determine the full load current at rated voltage. The physical size of the motor is directly related to its full load torque rating.

  For example, in comparing the torque ratings of the 100 hp 600 rpm and 3600 rpm motors in the full load speed example, you may recall that motor horsepower is proportional to torque time speed. Since the speed rating of the larger twelve pole motor is 1/6 that of the two pole motor, the torque rating is approximately six times that of the two pole motor.

- **Enclosures and Ventilation** - The motor nameplate usually identifies the type of enclosure and ventilation system, such as open type self-ventilated, totally enclosed fan cooled (TEFC), totally enclosed non-ventilated (TENV) and others. See “Motor Cooling” in previous discussion entitled “Motor Terms and Concepts.”

- **Insulation and Temperature Rise Ratings** - The motor nameplate identifies the Class of Insulation material used in the motor and its rated ambient temperature. Various types of materials can be used for insulation which are defined as Class A, Class B, Class F and Class H. IEEE Standards list temperature ratings as follows:

  Class A - 105° C
  Class B - 130° C
  Class F - 155° C
  Class H - 180° C

  When the rated temperature of the insulation materials is exceeded, it is estimated that the insulation life is decreased by 1/2 for every 10 degrees above the rating. By using higher temperature rated materials, more heat losses in the motor can be tolerated. Consequently, the horsepower rating of a motor can be increased in a given frame size.

  NEMA Standards specify permissible temperature rises above a 40° C ambient for motors. This is determined by the type of insulation in the motor, and other motor design and application considerations. Some motors operate at higher temperatures then others, but none should exceed the temperature rating of the insulation.

- **Service Factor** - A motor is rated by the manufacturer to produce a certain HP over a long period of time without damage to the motor. However, occasionally a motor might be operated intentionally or unintentionally above the rated HP. To protect against motor damage caused by the occasional excess current an electric motor is usually built with a margin of safety. The margin of safety is called the motor’s service factor.

The motor nameplate identifies a service factor; 1.0 or 1.15. This indicates overloads which may be carried by a motor under nameplate conditions without exceeding the maximum temperature recommended for the insulation. For example, a 100 hp motor with a 1.15 service factor can sustain a 15% overload (100 X 1.15 = 115 hp) continuously and will not exceed the temperature rating of the insulation in the motor, provided the ambient temperature is no greater than 40° C. Frequently motors are specified with 1.15 service factor to provide additional thermal capacity.

- **Time Ratings** - The motor nameplate identifies its time rating which can be continuous duty or short times, such as 60 minutes, 30 minutes, 15 minutes and 5 minutes. Obviously, at a specified horsepower, a motor operating continuously will generate more total losses and will require a larger frame size, compared to a motor operating intermittently. The short time ratings indicate the motor can carry the nameplate loads for the time specified without exceeding the rated temperature rise. After the short time, the motor must be permitted to cool to room temperature.

- **Locked Rotor KVA** - The motor nameplate identifies the locked rotor KVA with a code letter - A thru V. The locked rotor KVA may be a consideration when applying motors where limitations exist in the power distribution system. NEMA Standards have designated inrush KVA's for the various code letters.

SELF CHECK QUESTIONS AND EXERCISES

1. Match the parts of an AC motor with their correct description:

_____ Rotor	**A.**	External case that surrounds the motor.
_____ Housing	**B.**	A metal rod mounted in the case and supported by bearings.
_____ Stator	**C.**	A rotating iron core with wire windings. It is attached to the shaft.
_____ Shaft	**D.**	A stationary iron core with wire windings which is attached to the case.

2. Match the motor term with its definition

_____ Torque	**A.**	Speed is related to frequency and torque is related to current.
_____ Synchronous Speed	**B.**	The difference between the rotating magnetic field speed in the stator and the rotor speed.
_____ Slip	**C.**	The force tending to rotate an object. A turning force applied to a shaft, tending to cause rotation.
_____ Torque vs speed relationship	**D.**	The speed of an AC induction motor's rotating magnetic field.

True or False

3. _____ The most common type of AC motor is the wound rotor induction motor.

4. _____ Locked rotor current is the current flow required by a motor in order for it to start.

5. _____ Horsepower is a unit of power used to measure the rate at which work is done.

6. _____ NEMA design ratings for motors refer to motor current and voltage ratings.

SELF CHECK ANSWERS

1. Match the parts of an AC motor with their correct description:

__**C**__ Rotor	**A.** External case that surrounds the motor.
__**A**__ Housing	**B.** A metal rod mounted in the case and supported by bearings.
__**D**__ Stator	**C.** A rotating iron core with wire windings. It is attached to the shaft.
__**B**__ Shaft	**D.** A stationary iron core with wire windings which is attached to the case.

2. Match the motor term with its definition

__**C**__ Torque	**A.** Speed is related to frequency and torque is related to current.
__**D**__ Synchronous Speed	**B.** The difference between the rotating magnetic field speed in the stator and the rotor speed.
__**B**__ Slip	**C.** The force tending to rotate an object. A turning force applied to a shaft, tending to cause rotation.
__**A**__ Torque vs speed relationship	**D.** The speed of an AC induction motor's rotating magnetic field.

True or False

3. __**F**__ The most common type of AC motor is the wound rotor induction motor.

4. __**T**__ Locked rotor current is the current flow required by a motor in order for it to start.

5. __**T**__ Horsepower is a unit of power used to measure the rate at which work is done.

6. __**F**__ NEMA design ratings for motors refer to motor current and voltage ratings.

Chapter 2 - AC Drive Fundamentals

LEARNING OBJECTIVES

The participant will:

- Understand the difference between motor control using control products and AC drives
- Understand the benefits of AC drives
- Recognize applications for AC drives
- Understand the fundamentals of how AC drives work
- Understand the basics of load considerations and drive braking

PRIMARY PURPOSES OF MOTOR CONTROL

All electric motors require a control system. That control may be as simple as an ON/OFF switch, such as for an exhaust fan. Or, the operation may be so complex that a computer must be used in the control system, such as in an automobile assembly plant application. Both the exhaust fan and assembly plant electric motors are provided with start and stop control by their control systems. But the difference between their control systems is how they provide that control. In addition to start/stop control, a motor control system may also provide motor overload protection as well as motor speed and torque regulation.

Square D has a very comprehensive line of control products such as motor starters, contactors, switches, disconnects etc. These products are used in applications which include on/off controls with jog and reverse capabilities for pumps, compressors, fans, conveyors, meat cutters, textile looms, and wood and metalworking machines, just to name a few. Sometimes these types of control devices (switches, contactors, etc.), are called “across-the-line” starters. This is because full voltage and current are applied directly to the motor. An AC motor, as you learned in Chapter 1, when switched on like this tends to run at it’s maximum rated speed and torque. For many applications this is a perfectly acceptable situation. But there can be problems:

- The locked rotor current (also called “inrush current”) for a motor during starting can be six to thirteen times the normal operating current. This can cause problems if the electrical distribution system is already loaded near capacity, because excessive current draw can cause interruption of the whole system. The excessive starting current (multiplied by the number of motors in the facility) can cause the demand factor on the electric meter to become very large which may double or triple the electric bill.

- Another problem created by large locked rotor currents is the wear and tear on switchgear. When motors are allowed to draw maximum current, they can cause arcing and heat buildup that stresses contacts and switchgear. This stress causes equipment such as disconnects, and motor starters to wear out prematurely.

- A problem may also arise when loads are started at full torque. The starting torque of a squirrel cage motor can be as high as 140 percent of the normal operating torque. Sudden starting torque can damage the equipment or in the case of a conveyor, spill the materials being conveyed.

- It may also be important to control the time it takes a motor to stop. In some applications it is important that the load stop at exactly the time and location when the motor is de-energized. In normal motor operation, when a motor is de-energized, the load is allowed to coast to a stop, which means that the larger the load is, the longer the coasting time. This causes the load to be located at random, which may be unacceptable in certain applications. For example, if large cutting blades are turning at high speeds and are allowed to continue rotating after power is removed, then an unsafe condition could exist.

Because of one or more of these concerns, over the years, various methods have been tried to exert some control over motors. Some of the types of adjustable speed control that have been used are:

- Mechanical - Mechanical methods involve using devices such as brakes, clutches, and gearing to control motor speed. As you can imagine, these methods are not particularly efficient.

- Hydraulic transmission control - Physically the configuration includes a torque converter. This method is not used widely today:
  - Advantages: infinite speed control and moderate cost
  - Disadvantages: complex installation and high maintenance

- Electro-mechanical speed control - A combination of mechanical and electrical controls are used. This method of control has fallen from current favor, because it is very inefficient:
  - Advantages: simple and moderate cost, easy to maintain.
  - Disadvantages: discrete incremental control only. Uses wound-rotor motors which are usually non-stock, creating higher expenses and more maintenance problems.

- Eddy current - A magnetic clutch is used to adjust motor output speed in infinite increments. It is a simple idea, and it works. However, it is very inefficient and a lot of energy is lost through heat.
  - Advantages: simple
  - Disadvantages: poor efficiency and requires cooling, either by water or air.

- Electronic speed control (AC Drives) - Direct electronic controls are used most often to control speed:
  - Advantages: most efficient speed control, low maintenance, most flexible of all control schemes.
  - Disadvantages: can be more expensive at initial purchase, but saves money over time. Energy savings and reduced wear and tear on machinery will quickly repay the initial investment.

What Is The Difference Between a Soft Start and an AC Drive?

Square D makes different types of electronic motor control devices, two that you need to make sure you can tell the difference between are:

- Soft start devices (i.e., Altistart 23 and 46)

- AC drives (i.e., Altivar 16, 18, 56 and 66).

A soft start device reduces the voltage, thus reducing the current, at startup to relieve the stress on the motor and machinery. There are many, many applications where it is critical to do just this. In addition, the soft start can allow a motor to have smooth acceleration up to 100% operating speed and can control a motor’s smooth deceleration back down to zero as well.

An AC drive can also be a “soft start” device but it can also vary the speed and torque of the motor according to changing machine requirements. In other words, after start up, the motor does not have to run at 100% speed and torque but these elements can be varied to suit the application.

The soft start device reduces the voltage thus reducing the current at startup. While an AC drive <u>does not</u> reduce the startup torque. This can be a very significant factor depending upon the load application.

In short, **an AC drive can act as a soft start, but a soft start cannot act as an AC drive.**

Benefits of AC Drives

The AC drive has been around only since the 1970’s. The growing popularity of AC drives is due chiefly to their ability to provide adjustable speed control with standard NEMA B design squirrel cage motors. Other names for AC drives are variable frequency drive (VFD) and variable speed drive (VSD), but we’ll just call them AC drives.

Some of the reasons for the growing popularity of AC drives are:

- Energy savings, particularly for fans and pumps.
- Extended equipment life through reduced mechanical stress (belts, bearings).
- Elimination of excessive motor inrush current which in turn, extends useful motor life.
- Standard AC motors can be used. This means that off-the-shelf motors, which are easier to repair, purchase and maintain, not to mention less expensive, can be used.
- With an AC drive, retrofits from a DC or wound-rotor motor to a NEMA B squirrel cage motor are relatively easy.
- Solid state device which has no moving parts or contacts to wear out.

APPLICATIONS

AC drives can be applied in many of Square D's target industries. This list gives you a good idea of many of the types of applications and machines AC drives are used on:

Automotive

APPLICATION	MACHINES
Powertrain	Conveyors Tool Changers Transfer Lines Boring/Cutting machines
Forming Fabrication	Feeders Presses Conveyors Welder Shears
Assembly	Parts Positioning Hoists Welders Conveyors
Paint Shop	Pumps Ventilating Fans Conveyors
Special Machinery	Grinders Deburring Equipment Cutting Machines Wind Tunnels

Food & Beverage

APPLICATION	MACHINES
Bottling Lines	Conveyors Filling machines Capping machines Labeling Wrapping Pumps
Box & Bag Handling	Conveyors Filling, Folding, Labeling Wrapping Cutting Presses
Drying Freezing Air Conditioning	Fans Conveyors Transporters for freezing tunnels Screw pumps Archimedian screw
Bakery Confectionery Meat	Conveyors Crunchers Mixers Dough machines Pumps Agitators
Milk & Dairy	Pumps Conveyors Filling machines Mixers

Chemical

APPLICATION	MACHINES
Petroleum	Centrifugal Pumps Fans Dosing, Metering Pumps Granulator Mixers Container handling
Pharmacy	Mixers Agitators Packaging machines Fans
Fertilizers	Dosing conveyors, Pumps Crunchers Mixers Packaging machines Centrifugal Pumps Agitators
Paint	Dosing Pumps Crunchers Mixers Packaging machines Centrifugal pumps Agitators

Textile

APPLICATION	MACHINES
Fiber Fabrication Man Made Fibers	Bobbin winder Texturing machines Gear Pumps Mixers Extruder Twister, Doubler Drawing roller
Natural Fibers	Washers Conveyers Beam wrappers Carding machines Presser frames
Fiber Knitting	Knitters Circular rib knitters Weaver's loom Dyers Picking machines Flocking machines Printing machines Scrapers Bag handling machines Screw Pumps Archimedian screws
Clothing	Sewing machines Cutting machines Conveyors Washing machines Dry cleaning Ironer
Leather	Special machines Transporters Handling machines

Paper

APPLICATION	MACHINES
Paper Mills	Feeders Crushers Centrifugal Pumps Dryers Winding/Unwinding Rollers Coating machines Conveyors Cutting machines
Semi-Finished Product	Unwinding machines Glue pumps Packaging machines Conveyors Cutting machines
Printing	Ink pumps Conveyors Printing presses Assembling machine Folders Packaging machines

Wood

APPLICATION	MACHINES
Raw & Finished Lumber	Saws Ventilating Fans Pumps Chip Conveyors Transfer cars
Furniture	Grinders Saws Conveyors
Plywood	Ventilating Fans Pumps Washers Oven Conveyors Material Conveyors

Metallurgy

APPLICATION	MACHINES
Raw Product Oversized Material	Injectors Crushers Conveyors Pumps Fans
Semi-Finished Product	Wire Drawing machines Conveyors
Finished Product	Steel Rolling machines Wire Drawing machines Press, Cutting presses Plastic covering machines Metal finishing treatment Stitch seam welding machine

AC DRIVE THEORY

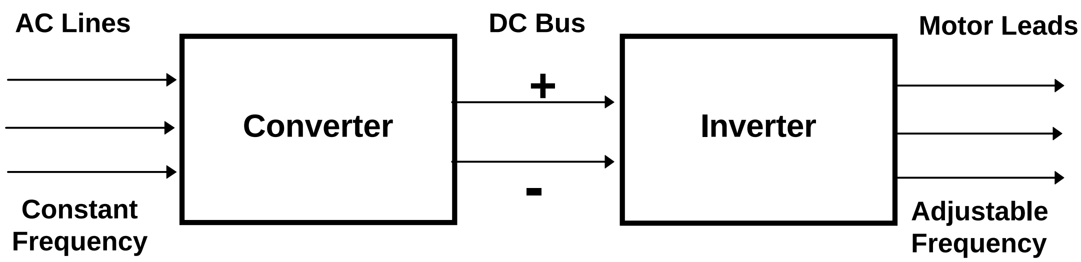
How Do AC Drives Work?

As you learned in Chapter 1, AC motor speed is controlled by frequency**. An AC drive is a device for controlling the speed of an AC motor by controlling the frequency of the voltage supplied to the motor.** It does this by first *converting* 3 phase 60 Hz AC power to DC power. Then, by various switching mechanisms, it *inverts* this DC power into a pseudo sine wave 3 phase adjustable frequency alternating current for the connected motor. Because of this, some people call AC drives “inverters,” although this is technically incorrect.

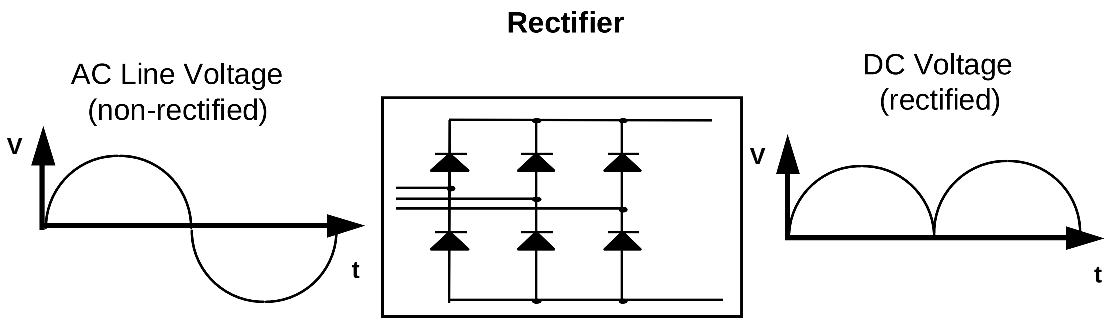
The frequency coming in to the converter has a fixed frequency of 60 Hz. However, the adjustable frequency coming out of the inverter and going to the motor can be varied to suit the application.

There are two general types of solid state frequency control systems available: six step and pulse width modulated (PWM) control. All of Square D AC drives use the pulse width modulation (PWM) method of frequency control, and that is the one we will concentrate on here.

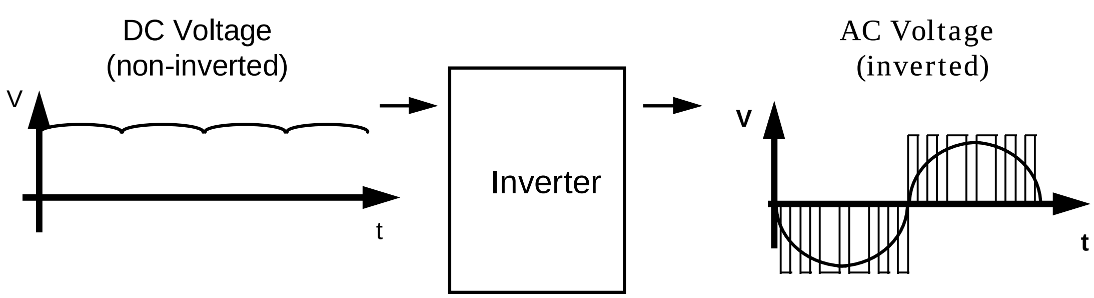
Let’s look at how an AC drive functions in a little more detail. The two main sections of a PWM drive are the converter and the inverter.



Three phase 60 Hz AC power is coming into the converter. The converter typically uses a rectifier (which is a solid state device that changes AC to DC) to change the incoming 60 Hz AC into a rectified DC voltage.



The DC voltage coming out of the converter is rather rough. Different types of filtering can be used to smooth out the rectified DC so that it is of a more or less constant voltage value. This filtering takes place between the converter and inverter stages. This “smoothed” DC is then sent on to the inverter.

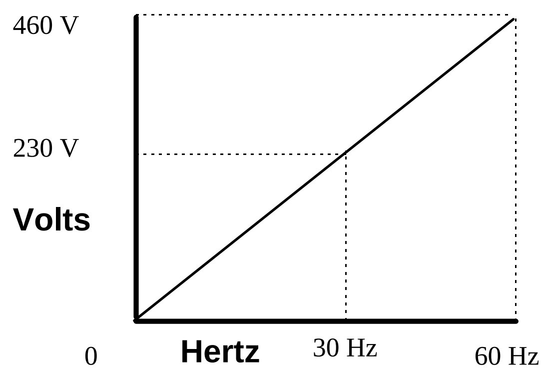


The inverter section produces an AC output which is fed to the motor. Positive and negative switching occurs within the Inverter which produces groups of voltage pulses. The output frequency of an PWM drive is controlled by applying positive pulses in one half cycle, and negative pulses in the next half cycle. The pulses within each group have varying widths that correspond to voltage values. Notice on the output side of the inverter that the narrow voltage pulses represent the lower voltage values on the sine wave and that the wider voltage pulses represent higher voltage sine wave values. The varying of the pulse widths gives this method its name of Pulse Width Modulation (PWM).

This diagram is only showing 6 pulses per half cycle. For each specific frequency, there is an optimum number of pulses and pulse widths that will closely simulate a pure sine wave.

Volts per Hertz Ratio

When current is applied to an induction motor it generates magnetic flux in its rotating field and torque is produced. This magnetic flux must remain constant in order to produce full-load torque. This is most important when running a motor at less than full speed. And since AC drives are used to provide slower running speeds, there must be a means of maintaining a constant magnetic flux in the motor. This method of magnetic flux control is called the volts-per-hertz ratio. With this method, the frequency and voltage must increase in the same proportion to maintain good torque production at the motor.



For example, if the frequency is 60 Hz and the voltage is 460 V, then the volts per Hertz ratio (460 divided by 60) would be 7.6 V/Hz. So, at half speed on a 460 V supplied system, the frequency would be 30 Hertz and the voltage applied to the motor would be 230 V and the ratio would still be maintained at 7.6 V/Hz.

This ratio pattern saves energy going to the motor, but it is also very critical to performance. The variable-frequency drive tries to maintain this ratio because if the ratio increases or decreases as motor speed changes, motor current can become unstable and torque can diminish. On the other hand, excessive current could damage or destroy the motor.

In a PWM drive the voltage change required to maintain a constant Volts-per-Hertz ratio as the frequency is changed is controlled by increasing or decreasing the widths of the pulses created by the inverter. And, a PWM drive can develop rated torque in the range of about 0.5 Hz and up. Multiple motors can be operated within the amperage rating of the drive (All motors will operate at the same frequency). This can be an advantage because all of the motors will change speed together and the control will be greater.

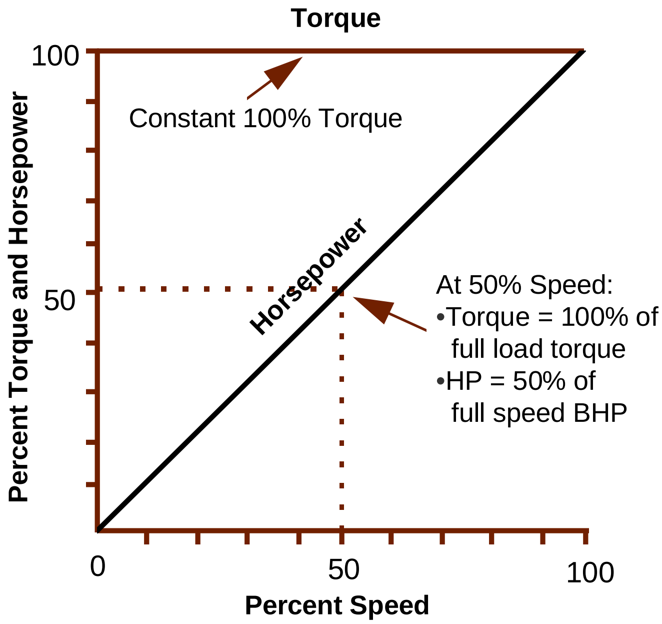
LOAD CONSIDERATIONS

The type of load that a motor drives is one of the most important application considerations when applying any type of AC drive. For some types of loads, the application considerations may be minimal. For other types of loads, extensive review may be required. Generally, loads can be grouped into three different categories:

- **Constant Torque Loads** - conveyors, hoists, drill presses, extruders, positive displacement pumps (torque of these pumps may be reduced at low speeds).
- **Variable Torque Loads** - fans, blower, propellers, centrifugal pumps.
- **Constant Horsepower Loads** - grinders, turret lathes, coil winders.

Constant Torque Loads

Constant torque loads are where applications **call for the same amount of driving torque throughout the entire operating speed range**. In other words, as the speed changes the load torque remains the same.



The chart shows speed on the bottom and torque on the left. The torque remains the same as the speed changes. Horsepower is effected, and varies proportionately with speed. Constant torque applications include everything that are not variable torque applications. In fact, almost everything <u>but</u> centrifugal fans and pumps are constant torque.

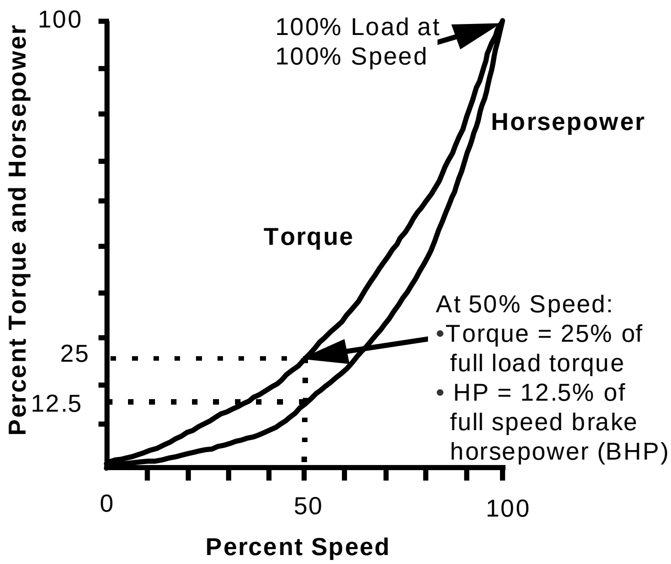
Variable Torque Loads

As was just mentioned, there are only two kinds of variable torque loads: centrifugal pumps and fans. With a variable torque load, the loading is a function of the speed. **Variable torque loads generally require low torque at low speeds and higher torque at higher speeds.**

Fans and pumps are designed to make air or water flow. As the rate of flow increases, the water or air has a greater change in speed put into it by the fan or pump, increasing its inertia. In addition to the inertia change, increased flow means increased friction from the pipes or ducts. An increase in friction requires more force (or torque) to make the air or water flow at that rate.

The effects that reduced speed control has on a variable torque fan or pump are summarized by a set of rules known as the **Affinity Laws**. The basic interpretation of these laws is quite simple:

1. Flow produced by the device is proportional to the motor speed.
2. Pressure produced by the device is proportional to the motor speed squared.
3. Horsepower required by the device is proportional to the motor speed cubed.



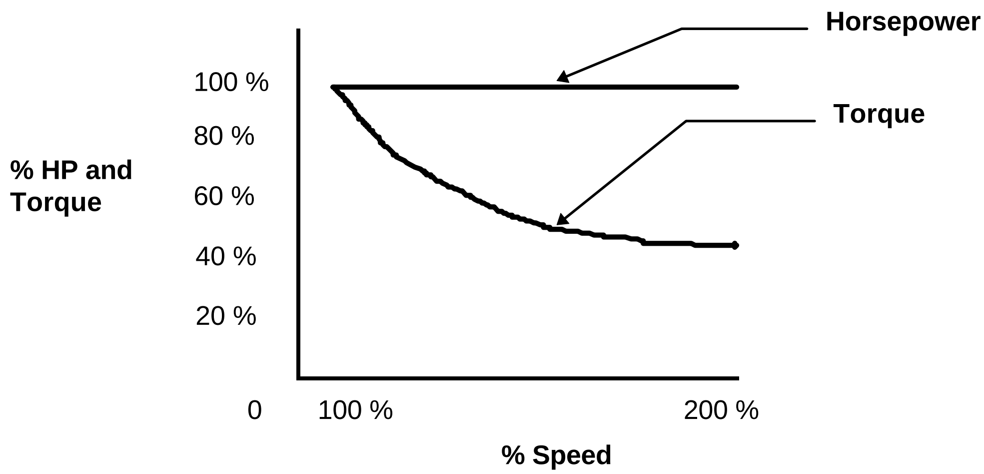
The cube law (third item) load is at the heart of energy savings. The change in speed is equal to the horsepower cubed. For example, you might expect a 50% change in speed would produce a 50% change in volume, and would require 50% of the horsepower. Luckily for us, this 50% change in speed must be cubed, representing only 12.5% of the horsepower required to run it at 100% speed. The reduction of horsepower means that it costs less to run the motor. When these savings are applied over yearly hours of operation, significant savings accumulate.

This table will help show these relationships:

% Speed	**% Torque**	**% HP**
100	100	100
90	81	72.9
80	64	51.2
70	49	34.3
60	36	21.6
50	25	12.5

Constant Horsepower

A constant horsepower load is when the motor torque required is above the motor's base speed (60 Hz). With a constant horsepower type of load, the torque loading is a function of the changing physical dimensions of the load. These types of applications would include grinders, turret lathes and winding reels. **Constant horsepower loads require high torque at low speeds and low torque at high speed**. While the torque and speed changes the horsepower remains constant.



For example, an empty reel winding a coil will require the least amount of torque, initially, and will be accelerated to the highest speed. As the coil builds up on the reel, the torque required will increase and the speed will be decreased.

BRAKING

An electric motor moves its load and demands whatever amount of power is required to get the load moving and keep it moving. Once the load is in motion it has inertia and will tend to want to stay in motion. So, while we must add energy to get the load into motion, we must somehow remove energy to stop it.

Some large motor loads develop high inertial forces when they are operating at high speed. If voltage is simply disconnected from the motor, the load may coast for several minutes before the shaft comes to a full stop. This is true in applications such as those involving large saw blades and grinding wheels. It's important for safety reasons to bring these loads to a smooth stop quickly.

In other load applications, such as elevators and cranes, the location where the load stops is as important as moving the load. This means that the motor shaft must stop moving at a precise time to place the load at its proper location.

There are several different types of braking techniques used, however we are only going to mention the two types used on Square D drives: DC braking and Dynamic braking.

In **DC braking**, DC current is applied to the stationary field of an AC motor when the stop button is depressed. Since the field is fixed and it replaces the rotating stator field, the rotor is quickly stopped by the alignment of the unlike magnetic fields between the rotating and stationary windings. The attraction between the rotating and stationary fields is so strong that the rotor is stopped quickly. This method of stopping is only effective at 10 Hz and below. The energy created with this type of braking will be dissipated in the rotor and care needs to be used when applying this type of braking. Square D uses this method to a limited degree.

Dynamic braking is used by Square D in its Altivar 66 drives. When the voltage is removed from a motor and the inertia of the load continues on in motion, the motor is being driven by the load until it coasts to a stop. Since the rotor will continue to spin, it will *produce* voltage and current in a manner similar to a generator. This generator action can be used to bring the rotor to a quick stop by sending the generated energy out to a resistor. There the energy is dissipated as heat through the resistor. The resistor will cause the rotor to generate very high levels of current, which produces magnetic forces on the shaft and causes it to stop quickly.

SELF CHECK QUESTIONS AND EXERCISES

True or False:

1. _____ "Across the Line" starters (and contactors) control both AC motor torque and speed.

2. _____ DC braking is when DC current is applied to the stator of an AC motor when the stop button is pressed.

3. _____ One advantage of AC drives is that less expensive, off-the-shelf AC motors (i.e., squirrel cage) that are easier to purchase and maintain can be used for multispeed applications.

4. _____ Variable torque loads generally require low torque at low speeds and higher torque at higher speeds.

5. _____ Examples of constant horsepower loads would be: fans, blowers, and centrifugal pumps.

6. _____ If the Volts per Hertz Ratio is not maintained motor current could become unstable and torque could diminish.

7. Match the parts of an AC drive:

_____ Inverter	A. This section smoothes rectified DC before it goes to the next section.
_____ DC bus filtering	B. This section changes DC into an adjustable frequency synthetic AC.
_____ Converter	C. This section changes 60 Hz AC power into DC.

SELF CHECK ANSWERS

True or False:

1. __F__ "Across the Line" starters (and contactors) control both AC motor torque and speed.

2. __T__ DC braking is when DC current is applied to the stator of an AC motor when the stop button is pressed.

3. __T__ One advantage of AC drives is that less expensive, off-the-shelf AC motors (i.e., squirrel cage) that are easier to purchase and maintain can be used for multispeed applications.

4. __T__ Variable torque loads generally require low torque at low speeds and higher torque at higher speeds.

5. __F__ Examples of constant horsepower loads would be: fans, blowers, and centrifugal pumps.

6. __T__ If the Volts per Hertz Ratio is not maintained motor current could become unstable and torque could diminish.

7. Match the parts of an AC drive:

__B__	Inverter	A. This section smoothes rectified DC before it goes to the next section.
__A__	DC bus filtering	B. This section changes DC into an adjustable frequency synthetic AC.
__C__	Converter	C. This section changes 60 Hz AC power into DC.

Chapter 3 - Square D AC Drive Products

LEARNING OBJECTIVES

The participant will be able to identify the basic features of the following drives:

- OMEGAPAK® 8803 and 8804
- ALTIVAR® 16, 18, 56, and 66

Note: The intent of this chapter is to give you an introduction to the terminology used when speaking about a drive's features with your customer.

OMEGAPAKS 8803® and 8804 OVERVIEW

Before starting to learn about Square D's newest AC drive products let's take a few moments to review what Square D AC drives are already in the market place. One drive type that your customers may inquire about is the Square D OMEGAPAK family (8803 or the 8804). The OMEGAPAK family of AC drives are designed to provide reliable, cost-effective speed control for AC induction motors. OMEGAPAK drives run both constant and variable torque applications. They are available in a variety of enclosure styles, and the OMEGAPAK family offers many optional features. Whatever the variable speed control needs — from pump and fan applications to machine and process control functions — the OMEGAPAK has been available for dependable control, effective motor protection and substantial energy savings.

Using pulse width modulated (PWM) inverter technology, OMEGAPAK drives minimize output current harmonic distortion, improve starting torque and provide smooth low-speed operation. This simple design uses a diode bridge rectifier to enhance reliability, reduce AC line noise and provide high displacement power factor. OMEGAPAK drives effectively replace throttling valve, dampers and other mechanical means of speed and flow control, adding control capabilities while, at the same time, reducing energy costs. Due to new product development the OMEGAPAK 8803 and 8804 are classified as older technology drives, therefore, Square D has placed these drives on the reduced availability list. That means that the OMEGAPAK drives can only be ordered as replacements for existing OMEGAPAK applications. For all new drive applications the ALTIVAR family should be recommended. This section has been included so you will have a basic knowledge about the drive if a user should call and request an OMEGAPAK drive.

The complete family of OMEGAPAK drives includes:

- Type PT - a constant/variable torque controller for low horsepower (1-10 HP) applications;
- Type VT - a variable torque drive suitable for pump, fan and blower control;
- Type CT - a constant torque drive featuring unique connectivity options, making it particularly useful in remote operation, integrated automation and machine — and process — control systems.

Let's take a look at the features of two of the OMEGAPAK drives, the OMEGAPAK 8804 and the OMEGAPAK 8803.

OMEGAPAK 8804®

OMEGAPAK Type PT

OMEGAPAK Class 8804 Type PT family of AC drives offers reliable, cost-effective speed control for low horsepower, standard three-phase AC induction motors. Compact and flexible in design, the PT provides controlled acceleration and deceleration for a variety of applications. Features include:

- Fuseless output short circuit and ground fault protection
- UL listed fault withstand rating of 65,000 RMS symmetrical construction
- Extensive options are offered for customizing PT drives:
  - Pilot device options
  - Option boards
  - Dynamic braking
  - Power options

OMEGAPAK Type VT

The OMEGAPAK VT drive was engineered specifically for variable torque applications such as centrifugal pumps and fans. OMEGAPAK Type VT drives require less electrical power than mechanical methods of liquid or air flow control to produce a given rate of flow. Highly efficient in operating standard AC squirrel cage motors, VT drives produce significant energy savings combined with top-notch performance and reliability. The OMEGAPAK VT family provides:

- Fuseless output and ground fault protection
- UL listed fault withstand rating of 65,000 RMS symmetrical amperes
- Solid state overload protection
- Analog follower input
- Versatile construction with open, wall-mounted and motor control center style enclosures are available
- Extensive options for customizing VT drives

OMEGAPAK Type CT

The OMEGAPAK CT drive was engineered specifically for constant torque applications such as process control and machine applications, for example. The sine–coded PWM output provides improved starting torque and reduces motor heating effects. The diode bridge provides a high displacement power factor and reduces AC line noise. Standard and optional features provide the flexibility necessary for effective variable speed applications. The OMEGAPAK CT family provides:

- Fuseless output and ground fault protection
- UL listed fault withstand rating of 65,000 RMS symmetrical amperes
- High starting torque
- Solid state overload protection
- Drive connectivity through serial communications with SY/MAX® programmable controllers for motion control applications in sophisticated automation systems.

Additional Features

- User-selectable process control functions
- User-programmable and configurable input ports
- Isolated RS-422 serial communications

OMEGAPAK 8803

OMEGAPAK Class 8803 Standard Enclosed Drives provide customers with a simple, reliable and safe method of using and installing OMEGAPAK Type P, Constant, and Variable Torque AC Drives. The OMEGAPAK 8803 drives have the following standard and optional features:

Standard Features:

- Manufactured in compliance with ISO 9002
- Three power options for enclosed drives
- Three control options for enclosed drives
- Options for Standard Enclosed Drives are arranged to provide ease of access and wire termination
- NEMA Type 12 enclosure
- Panel mounted line fuses provided as standard to protect drive regardless of disconnect means
- Internal Stirring Fan - eliminates isolated heat spots and ensure maximum ambient temperature exposure
- 120 Volt User Control Power
- User mounting space - for three 6.75 inch DIN rails to accommodate user mounted devices

Optional Features:

- Choice of Door-Interlocked Disconnect Means:
  - Circuit Breaker
  - Disconnect switch (not fused)
- Input Contactor - provides automatic AC drive isolation from the line in the event of drive faults and timed isolation upon command to stop
- Bypass Contactor - drive isolation and manual bypass provide emergency full speed operation in the event of drive fault
- Choice of Operator Control - 2 - wire maintained control with Forward/Reverse selector switch

Available Field Installed Options

- Do-it-yourself kits available for NEMA Type 12 enclosures, control, power and disconnect options
- Dynamic Braking
- Serial Communications
- Commissioning Terminal
- +/- 10 v Speed Reference Interface
- 200 Hertz Software

ALTIVAR OVERVIEW

Now that you have reviewed what Square D AC drives are in the marketplace, let's continue on and learn about Square D's newest AC drive family, the ALTIVAR drives. The complete ALTIVAR drive family (ALTIVAR 16, 18, 56, and 66) provides compact size and full-featured performance for a wide range of applications and motor sizes. Manufactured to ISO 9000 series standards, ALTIVAR drives meet UL, CSA, IEC and VDE standards. Because the drives were developed as a global product, the ALTIVAR drive family can meet your customer's needs locally as well as worldwide. The ALTIVAR family is a growing line of advanced drives from Square D.

ALTIVAR® 16 FEATURES

With the ALTIVAR 16 your customers no longer have to sacrifice full-featured AC drive capability for compact size. Now, you can give your customers both with the remarkably compact ALTIVAR 16 AC drive. Because it is simple and modular, the ALTIVAR 16 is a viable replacement for other variable speed motor controls. With a higher degree of versatility and control than conventional starters, the ALTIVAR 16 drive is a very cost-effective yet advanced starting option for controlling motors of 5 HP and less. The basic unit requires no programming — wire in, wire out, and its ready to run. However, the ALTIVAR 16 can be custom programmed with a plug-in keypad, personal computer or programmable controller. You can add even more functionality with a plug-in option card pre-configured for your customer's particular application. Because all of this performance comes in a very compact package, the ALTIVAR 16 drive makes it easy to retrofit constant speed motor controls or to substantially reduce panel size. Features include:

- Rated power size ranges from 1/2 to 3 HP (200-240V AC) and 1 to 5 HP (400-460V AC)
- Protection against short circuits:
  - Between output phases
  - Between output phase and ground
  - In internal power supplies
- Overload and overtemperature protection
- Overvoltage and undervoltage protection
- Protection against phase loss (ATV16U-N4 only)
- NEMA 1, IP30
- UL, CSA, IEC, VDE
- Factory-configured option cards for specific industry segments
  - General use / material handling
  - Centrifugal pumps, fans
  - Textile, wood process, high speed motors

The features for each industry include:

- **General use / material handling**
  - S ramp - Used for "S" Curve Acceleration and Deceleration smoothness and reduces consequent shock as the drive controller accelerates or decelerates from current speed to setpoint speed.
  - Fault reset - Allows drive to reset the resettable faults when in Terminal Command mode.
  - Jog
  - Preset speeds
  - Three stopping methods
    - Freewheel - Allows the motor and load to coast to a stop due to normal design of the system
    - Ramp to Stop - Allows the motor and load to ramp to a complete stop within a settable amount of time
    - Brake control - Dynamic braking or DC injection braking
- **Centrifugal pumps, fans**
  - Variable torque volts/Hz ratio
  - 10 Khz switching frequency - Helps reduce audible motor noise
  - Automatic restart - When a fault occurs the drive will attempt to restart for a maximum of 5 times.
  - Jump frequencies - Reduces mechanical resonance in a fan or pump.
  - Controlled stop on loss of input power

- Automatic/manual switching input - Switches the speed reference to the drive from auto to manual.

- **Textile, wood process, high speed motors**

  - Inhibited slip compensation
  - Jog
  - Freewheel stop
  - Switch to ramp 2 - Allows different acceleration rates based on either a logic input or a frequency level
  - Automatic catching a spinning load - Allows drive to operate into a spinning motor.
  - Frequency range extended to 400 hz

ALTIVAR® 66 FEATURES

The AC drives market is now opening up into areas previously dominated by standard motor control applications such as fans, pumps and conveyors. The ALTIVAR 66 product range covers the growing need of variable speed drives, for asynchronous motors from 3 to 350 HP (CT). The ALTIVAR 66 drive is in synergy with the ALTIVAR 16 drive to cover the market for variable speed drive applications. The range of the ALTIVAR 66 is comprised of the following parts:

- Basic product
- Additions that support and enhance the functionality of the base product and
- Standard enclosure packages

Due to the available horsepower ranges of the ALTIVAR 66 and 56 drives, maintenance and service issues are greatly simplified. Since the horsepower range goes from 3 to 350 HP (CT) users and distributors are able to reduce their drive inventory. There are 3 centers of production and distribution for the ALTIVAR family:

- Europe
- Southeast Asia
- United States (Raleigh)

When the ALTIVAR 66 arrives at your location or the customer's site the drive is set up for operation with average performance and no factory made adjustments. The following are the factory settings.

Factory Settings:

- Constant torque
- Two-wire control
- Rated motor frequency according to supply frequency
- Motor voltage:

  - 50 Hz detected sets drive up for 400V
  - 60 Hz detected sets drive up for 460V

- Adjustments:

  - Acceleration ---> 3s
  - Deceleration ---> 3s
  - Low Speed ---> 0 Hz
  - High Speed ---> 50 or 60 Hz depending on supply frequency

- Functions:

  - Slip compensation - adjusting the volts per hertz ratio in the drive
  - DC injection for frequency < 0.1 Hz (70% of current for a half of second)

Sensorless Vector Control

Normally when an AC drive provides vector control, the drive requires a feedback device such as a tachometer, resolver, or encoder. These feedback devices provide the motor's shaft speed and position feedback to the drive. The AC drive in turn, uses the feedback along with a mathematical motor model, and current vectors to determine and control the actual speed, torque, and power produced by the motor on a continuous basis.

As technology advanced, several methods of controlling torque at low frequencies emerged without a need for the feedback devices. This method of control is called Sensorless Vector Control. Sensorless Vector Control is a method used by the ALTIVAR 66 AC drive to produce a constant torque at the load without having the motor provide any feedback to the AC drive. To accomplish this the AC drive must increase the control voltage to the motor along with the frequency to produce a constant stator magnetic flux field in the motor. The ALTIVAR 66 drive accomplishes constant torque by using a mathematical motor model. By automatically measuring the motor's stator resistance and the mutual inductance of the motor and with the drive's onboard database of motor models, the drive's micro-processor is able to refine the mathematical model on the fly and accurately control the motor's constant torque without the need of motor feedback devices.

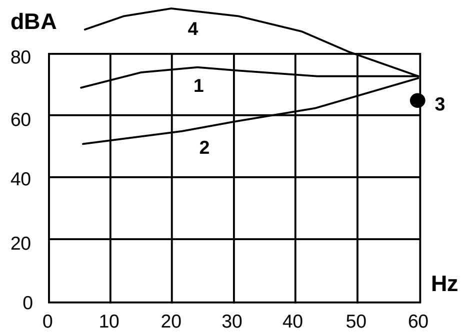
Reduction of Motor Noise

Reduction of motor noise is accomplished in the ALTIVAR 66 by the following methods:

- Random frequency generation
- Combination of fixed switching frequency and random frequency
- Reduction of unpleasant switching frequency noise (less high-pitch noise)

Motor Noise Comparison Chart

The graph below shows the relationship between the drive's switching frequency (Hz) and the motor's noise level (dBA) when connected directly across a 60 Hz line. Notice by switching the carrier frequency at different frequencies (4kHz, 10kHz, etc.) the actual noise level produced by the motor can be reduced. This can be demonstrated by comparing line number 2 at different frequencies (10, 20, etc.) on the graph to the dot, number 3, which is the normal amount of noise a motor generates when across a 60 Hz line.



1 - switching at 4 kHz with random carrier

2 - switching at 10 kHz with random carrier

3 - motor directly connected to AC supply

4 - 8803 P

Drive Interfaces

The ALTIVAR 66 drive interfaces are broken down into the following areas.

- Operator Interfaces
  - Start-Stop
  - Other Controls
  - Programmable Controllers
  - Building Management
  - Supervisory Control
- Input/Output Interfaces – Examples of I/O interfaces are indicators, metering, etc.

Base product Input/Output assignments for the Analog, Digital, and Relay terminals

The following legend and table shows what the default drive assignments are and what they can be reassigned to:

Legend:

AI = Analog Input
AO = Analog Output
LI = Logic Input
LO = Logic Output
R = Relay

Default assignment	Reassignment	I/O
Speed reference	Current limit, motor voltage	AI1
Speed reference	Current limit, motor voltage	AI2
Output frequency	See configuration manual	AO1
Output current	See configuration manual	AO2
Run Permissive (2-wire)	NO	LI1
Run Forward (2-wire)	NO	LI2
Run Reverse (2-wire)	See configuration manual	LI3
Jog	See configuration manual	LI4
Speed reached	See configuration manual	LO1
Current limit reached	See configuration manual	LO2
Speed controller fault	NO	R1
Speed controller operating	See configuration manual	R2

Protection

AC Supply Protection

- Overvoltage: +10% at 240V, +15% at 460 V
- Undervoltage: -10% at 208V, -15% at 400 V

  - Time of a fault is less than 10ms the drive will Reset (t < 10ms - Reset)
  - If time is greater than 10ms but less than 200ms - Reset current and Reset the ramp **or** Reset current without resetting the ramp (restart with automatic catching of spinning load without time constant, by measuring generator E)
  - Time greater than 200ms - Activate fault relay

- Phase failure

  - Time greater than 1 second (t > 1s) - Activation of fault relay with choice of stop mode: freewheel, ramp, fast.

- AC supply interference

  - Interference suppression: provided in the basic product (electromagnetic compatibility, IEC-VDE standards)
  - high energy overvoltage: additional inductors

- Braking in the event of supply failure: switching mode supply

  - programmable function

Other ALTIVAR 66 Protection

- Short circuits on +/- 10V, +/- 24 V supplies: electronic
- Short circuits between phases: Frame 1, 2 - Intelligent Power Module (IPM). Frame 3 to 7 - desaturation measurement
- Short circuits between phase and earth: Frame 1, 2 - IPM. Frame 3 to 7 – current sensor
- Controller overheating: fault - Frame 1, 2 - IPM. Frame 3 to 7 - NTC (negative temperature coefficient) probe. Early warning - ventilation fault. Frame 3 to 7 - NTC probe.
- Detection for presence of motor current reading - Measurement of 2 phases
- Current limit: 2 times In (nominal current) rms for 200 ms - on starting and/or on a load surge
- DC bus overvoltage: 850 V for the 400/460 V controller
- DC bus undervoltage: 480 V for the 400/460 V controller
- Monitoring of charging circuit for filtering capacitors
- Mechanical locating devices for connectors

Motor Protection

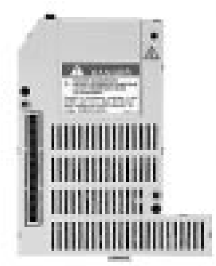
- Adjustable current limit: 45 to 150% of the controller rated current
- Motor thermal overload saved on loss of supply
    - Integrates time constants of various motors (overheating and cooling)
    - Self-ventilated motor
    - Motor ventilated motor
    - Client motor, derated motor special profile to be programmed
        - motor rated current
        - minimum speed at full load
        - maximum motor torque at zero speed
- Detection of motor phase loss (yes-no)
- Recognition of external client fault
- Adjustment of the V/Hz ratio at the motor load
- Adjustment of the frequency in the event of motor overload

Protection of the Driven Mechanism

- Limitation of excessive torque
- 4 quadrant torque regulation
- Limitation of speed surges
- Machine overloads
- Inhibition of critical operating speeds
- Inhibition of surges when restarting following a supply break
- Machine safety
- Protection of the process

Options:

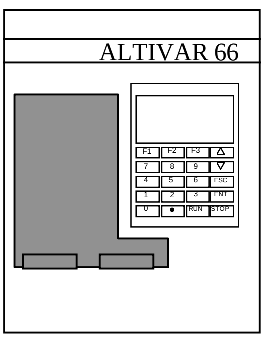
I/O Extension Modules (B1, B2)



When a B1 or B2 I/O extension card is installed the controller these additional features become available:

- Additional logic and analog functions (see table below)
- Automatic I/O configuration of I/O extension module when module is added to the ALTIVAR drive
- Communications (see Communications next page.)

B1 and B2 I/O Extension Cards have the following features:



	Logic inputs	Analog inputs	Logic outputs	Analog outputs
B1	4 - 24VDC	2	2	1
B2	8 - 115VAC	2	2	1

Communication

The communication can be connected through either one of the following extension cards:

- B1 extension module
- B2 extension module
- Communication card carrier module

With the card installed the ALTIVAR can communicate to the following industrial protocols:

- Uni-Telway
- Modbus RTU/ASCII
- Modbus+

Dynamic Braking

A braking system is required when the natural deceleration time of the motor and attached equipment is longer than the deceleration ramp. Dynamic Braking is often the best choice when decelerating from high speeds. For an explanation of Dynamic Braking, refer back to Chapter 2 “Braking.”

Major Components for Dynamic Braking

- A power semi-conductor to switch resistor circuit in and out.
- Separately mounted braking resistor

ALTIVAR® 56 FEATURES FOR FAN AND PUMP APPLICATIONS

Design Philosophy

The ALTIVAR 56 was designed mainly with the construction market in mind. The ALTIVAR 56 is a Variable Torque Fan and Pump Drive available in ratings from 1 - 100 HP 460 V and 1 - 50 HP 230/208 V. These products can be configured to operate in a “Low Noise” mode using a higher switching frequency by derating the products. Low Noise ratings are available from 1 - 75 HP 460 V and 1 - 40 HP 230/208 V.

The ALTIVAR 56 drive is based upon the popular ATV66 drive and uses many of the same spare parts, hardware and options. As an application specific product, much of the complexity of the ALTIVAR 66 has been eliminated by optimizing the performance for fan and pump applications.

The ALTIVAR 56 is also available as a UL listed Class 8839 combination package mounted on a back panel with a NEMA 1 contactor “BELE” box beneath the drive. The ALTIVAR 56 combination drives are available in 3 “Package” designs:

ATV56 Combo Package (W) - includes 200kAIC rated drive input fuses, MagGuard circuit breaker with provisions for lock out and H-O-A selector switch with manual speed potentiometer.

BELE Box Features

Bypass Package (Y) - includes drive isolation contactor, IEC motor stator with class 10 overload, 200 kAIC rated drive input fuses, control transformer, MagGuard circuit breaker with provision for lock out. AFC-Off-Byp, and H-O-A selector switch with manual speed potentiometer.

Remote Starter Bypass Package (Z) - includes drive isolation contactor, IEC motor stator with class 10 overload, 200 kAIC rated drive input fuses, control transformer, MagGuard circuit breaker with provision for lock out. AFC-Off-Byp, and H-O-A selector switch with manual potentiometer.

The features of the ALTIVAR 56 are as follows:

- Variable torque for fan & pump applications
- Easy setup for quick installation
- Limited “advanced” features
    - Simplified menu system
    - Limits programming decisions customer has to make
    - Simplified documentation required to support software

Language

The ALTIVAR can communicate in one of the following languages:

- English
- Spanish
- French

Design Notables

- Logic input defaults:
  - LI3 - AUTO/MANUAL
  - LI4 - AUTO RUN
- When using Class 8839 ATV56 DO NOT turn on BYPASS function
  - Class 8839 uses external relays for bypass sequencing
- Even though Run Reverse can not be configured as a logic input, the controller can still reverse phase rotation
  - If the controller is configured for AI1/AI2 summing and AI2 is multiplied by (-1) and the result is a negative value, the controller will run in reverse

ALTIVAR® 18 FEATURES

Overview

The ALTIVAR 18 is a simple and compact OEM drive. The ALTIVAR 18 drive is similar to the ATV 16 but is non-modular and has an extended horsepower range. The drive is capable of controlling motors of 20 HP and less. With built-in filters, the ALTIVAR 18 meets CE standards. With the cost effectiveness and advanced technology of the drive it can be used in a wide variety of applications. Typical examples are:

- Pumps / Compressors
- Fans
- Horizontal handling
- Packing / Packaging
- Special machines:
  - Woodworking
  - Textile
  - Mixers
  - Blenders

Features:

Choice of type of Volts/Hz control

When setting the Volts/Hz control in the ALTIVAR's menu, you will choose one of the following parameters:

- P - will set the drive to V/F variable torque for Pumps / Compressors (Centrifugal and metering pumps, screw compressors)
- n - will set the drive to vector control for Horizontal handling, Packing / Packaging, Special machines
- nld - will set the drive to energy saving for Fans
- Switching frequency
- Auto DC injection at standstill f<0.5Hz - Horizontal handling, Packing / Packaging, Special machines

Drive Customization

- Autotuning - Horizontal handling, Packing / Packaging, Special machines
- Auto-adaptation of the deceleration ramp - Pumps / Compressors, Fans, Horizontal handling, Packing / Packaging, Special machines
- Auto speed retrieval (catch on the fly) - Pumps / Compressors, Fans, Horizontal handling, Packing / Packaging, Special machines
- Automatic restart - Pumps / Compressors, Fans
- Controlled stopping on main failure - Horizontal handling and Special machines

Application functions

- Skip frequencies - Fans, Mixers, and Blenders
- Low-speed operating time limit - Pumps / Compressors

Application Customization

- Analog inputs
  - Summing - Horizontal handling, Packing / Packaging, and Special machines
  - PI regulator - Pumps / Compressors, Fans

Logic Inputs

- 2 directions of operation - Horizontal handling, Packing / Packaging, and Special machines
- DC injection - Fans, Mixers, and Blenders
- Fast stop - Horizontal handling, Packing / Packaging, and Special machines
- Jog - Horizontal handling, Packing / Packaging, and Special machines
- Preset speeds - Fans, Horizontal handling, Packing / Packaging, and Special machines

Logic Inputs

- Speed reference reached - Pumps / Compressors, Fans, Horizontal handling
- Frequency threshold reached - Pumps / Compressors, Packing / Packaging, Mixers, and Blenders

Range

- 17 ratings in 5 sizes - Built-in EMC filters through the range
- .5 HP through 20 HP
- IEC, UL, CSA, EN, CE mark

Equivalent ATV 16 / ATV 18

ATV 16

- Rated controller current = 1.1 rated motor current
- Thermal current ratting (Ith) setting:
  - 0.45 to 1.05 In controller
  - 0.45 X 1.1 In motor = 0.5 In motor
  - 1.05 X 1.1 In motor = 1.15 In motor

ATV 18

- Rated controller current = Rated motor current
- Thermal current rating (Ith) setting: 0.5 to 1.15 In motor

Performance:

- Drive quality
  - Smooth motor rotation without jolts at low speed ($f \leq 5$ Hz)
  - Stable motor current, irrespective of the motor's load state and speed (little pulsating torque)

- Speed
  - Frequency range: 0.5 to 320 Hz
  - Speed range: constant torque 1:50 (1 to 50 Hz)
- Reference
  - Sampling time 5 ms
  - Frequency resolution with analogue reference (10 bits, 1024 points)
    - 0.1 Hz to 100 Hz
    - 0.3 Hz to 320 Hz
- Frequency accuracy with analog reference: ± 0.3% of maximum set frequency

SELF CHECK QUESTIONS AND EXERCISES

Use the information presented in this chapter to answer the following:

1. Due to new product development OMEGAPAK (8803 and 8804) drives are limited in their availability. _____ (T or F)

2. When the ALTIVAR 66 arrives at your location the drive is set up for: (Circle the correct answer.)

A. operation with average performance and no factory made adjustments.
B. operation with average performance and some factory made adjustments.
C. operation with optimized performance and no factory made adjustments.
D. operation with optimized performance and all factory made adjustments.

3. The ALTIVAR 66 helps reduce motor noise by:

A. Random frequency generation, fixed switching frequency, and a reduction of unpleasant fixed switching frequency noise (less high-pitch noise)
B. Constant frequency generation, fixed switching frequency, and a reduction of unpleasant switching frequency (less high-pitch noise)
C. Random frequency generation, combination of fixed switching frequency and random frequency, and a reduction of unpleasant switching frequency (less high-pitch noise)

4. The software that runs the ALTIVAR 56 was designed for the ________ market.

A. Industrial
B. Construction
C. Residential
D. All of the above

5. The major differences between the ALTIVAR 66 and the ALTIVAR 56 are:

A. Variable torque for fan & pump applications, easy setup for quick installation, removal of “advance” features, removal of constant torque, removal of communications.
B. Constant torque for fan & pump applications, easy setup for quick installation, additional “advance” features, additional communications.
C. There are no major differences between the ALTIVAR 66 and the ALTIVAR 56

SELF CHECK ANSWERS

1. Due to new product development OMEGAPAK (8803 and 8804) drives are limited in their availability. **T** (T or F)

2. When the ALTIVAR 66 arrives at your location the drive is set up for: (Circle the correct answer.)

A. operation with average performance and no factory made adjustments.
B. operation with average performance and some factory made adjustments.
C. operation with optimized performance and no factory made adjustments.
D. operation with optimized performance and all factory made adjustments.

3. The ALTIVAR 66 helps reduce motor noise by:

A. Random frequency generation, fixed switching frequency, and a reduction of unpleasant fixed switching frequency noise (less high-pitch noise)
B. Constant frequency generation, fixed switching frequency, and a reduction of unpleasant switching frequency (less high-pitch noise)
C. Random frequency generation, combination of fixed switching frequency and random frequency, and a reduction of unpleasant switching frequency (less high-pitch noise)

4. The software that runs the ALTIVAR 56 was designed for the ________ market.

A. Industrial
B. Construction
C. Residential
D. All of the above

5. The major differences between the ALTIVAR 66 and the ALTIVAR 56 are:

A. Variable torque for fan & pump applications, easy setup for quick installation, removal of “advance” features, removal of constant torque, removal of communications.
B. Constant torque for fan & pump applications, easy setup for quick installation, additional “advance” features, additional communications.
C. There are no major differences between the ALTIVAR 66 and the ALTIVAR 56

Chapter 4 - AC Drive Types

LEARNING OBJECTIVES

The participant will:

- Be able to identify an open type drive
- Be able to identify an enclosed type drive
- Be able to identify a MCC type drive

DRIVE TYPE OVERVIEW

In this course, so far, you have learned about AC motor fundamentals, AC drives fundamentals, and Square D's AC drive products. In this chapter you will learn about the types of AC drives. AC drives can be categorized into three types; open type, enclosed type, or Motor Control Center (MCC). Square D's AC drives can be utilized for all three types. Let's explore each drive type.

OPEN TYPE DRIVES

Definition of Open Type Drive

An open type drive is where the user buys the drive as a component piece, to use as is or to be built into their own enclosure or machine. The user installs the drive into their enclosure and does all of the interfacing necessary for the drive to function properly in the application.

When assisting a user in selecting an open type drive it is beneficial to ask the user if the drive will reside inside an enclosure. If the answer is yes, then you should ask for the dimensions of the allotted drive space in the enclosure, to ensure that the drive will physically fit in the enclosure. This practice of asking the user for the drive's space dimensions, whether the drive is a new installation or a retrofit, will be a value added feature to your user's satisfaction level and save time on both sides.

It is also beneficial to ask the user how they are dissipating the heat inside their enclosure. This way you can verify that the drive will fit correctly and operate in the environment of the user's enclosure. Identifying if a user has an open type drive will be covered in the section on "How To Identify The Drive Type," later in this chapter.

Which Square D AC Drives Can Be Used For Open Type Applications?

Of the drives covered in this course, the ALTIVAR 16, 18, and 66 can be used for open type applications.

ENCLOSED TYPE DRIVES

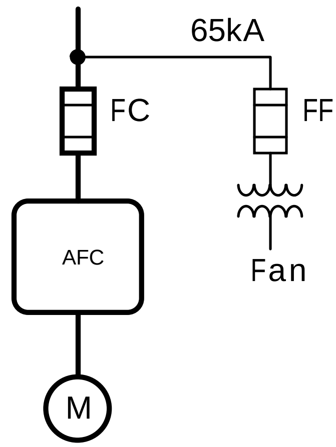
Definition of Enclosed Type Drive

An enclosed type drive (Class 8839) is where the a user requests Square D to pre-engineer the drive and enclosure. The Square D Columbia plant in South Carolina builds our enclosed type drives. Items such as Bypass Control Schemes, Hand-Off-Auto Selector Switches, Start/Stop pushbuttons, Jogging selectors, Speed pots, etc. can be incorporated into the drive enclosure. Enclosed Type drives are offered in NEMA Type 1, and Type 12 enclosures. Identifying if a user has an enclosed type drive will be covered in the section on “How To Identify The Drive Type,” later in this chapter.

Which Square D AC Drives Can Be Used For Enclosed Type Applications?

Of the drives covered in this course, the ALTIVAR 56, and 66 can be used for enclosed type applications. The ALTIVAR 56 is only available as an enclosed type drive.

Enclosure Power Circuits



Once the drive has been selected for the application, the next step is to choose what power circuit configuration will be mounted into the enclosure. There are several to choose from depending on the application. When choosing a power circuit there are many factors to take into consideration:

- The National Electric Code (NEC)
- Plant practices and local building codes
- Selection for minimum voltage drops
- Methods to reduce or eliminate magnetic radiation or electrical noise and
- The actual current carrying capacity of the cables based on the drive size and loading.

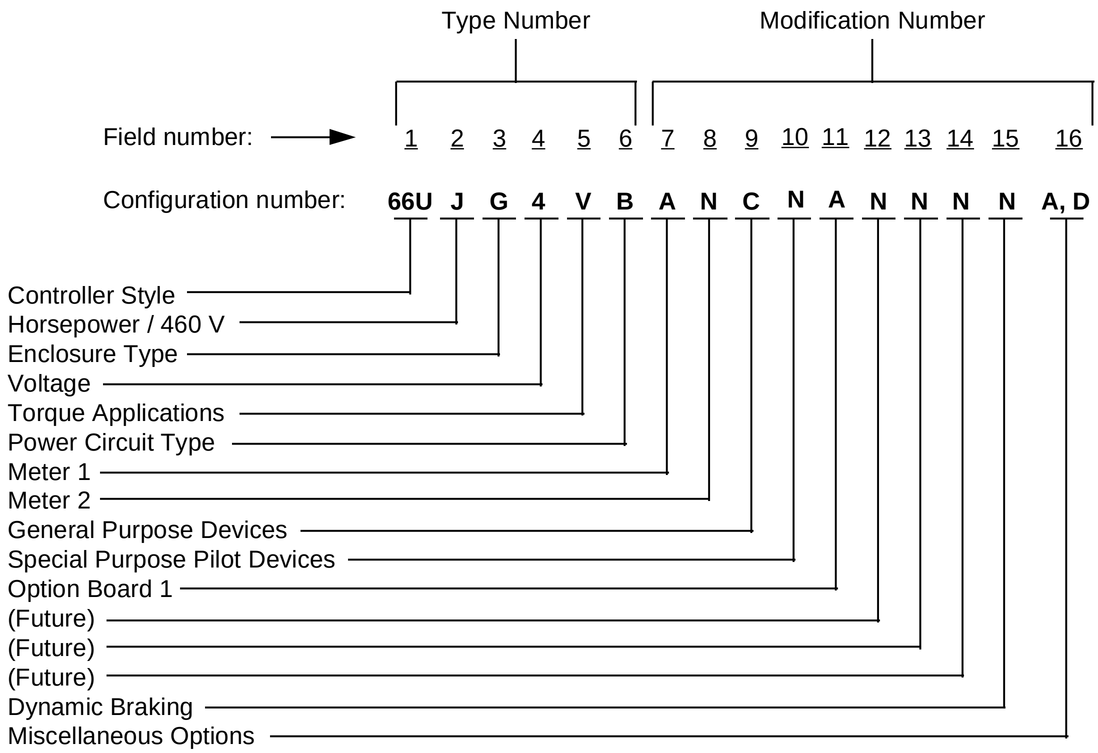
The power circuit also serves as a reference point when it comes to wiring electrical equipment and other components needed for drive technology. When working with enclosed drive enclosures, the letters A through K are used in the enclosure's configuration number to differentiate the power circuits required by the user for their application. For a better understanding of how each power circuit for the enclosure is configured and the features for each circuit, see "Enclosed Power Circuits" in this chapter.

Identification System for Enclosed ALTIVAR Drives Excluding the ALTIVAR 56

An enclosed drive configuration number uses Class, Type and Modification Numbers to identify the basic drive and optional devices. Fields 1 through 6 (see below) defines the basic type number, and the options are defined by modification numbers. The 16 digit configuration number that appears on all customer documents indicates the type and form number, and deletes the field designation. This new 16 digit number will be compatible with future Square D product selectors and Q2C systems.

	Type Number						Modification Number									
Field number: →	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Configuration number:	**66U**	**J**	**G**	**4**	**V**	**B**	**A**	**N**	**C**	**N**	**A**	**N**	**N**	**N**	**N**	**A, D**

The configuration number for the enclosed drive breaks down into the following categories



Now, let's suppose that a user calls in and requests an analog speed meter for their enclosure. The following example demonstrates how a user's modification is changed into a modification letter and how that letter is displayed in the configuration number.

Example: A user has ordered an analog speed meter for their enclosed drive. If you look at the chart below, you will see that the analog percent speed meter is A07 (from Table 4 of the Class 8839 ALTIVAR 66 Enclosed Adjustable Speed Drive Controllers Price Guide, Pub. No. 8839PL9601).

Meter 1 Mod	Meter 2 Mod	Meter Description	Price
A07	A08	Analog Percent Speed	$404.
B07	B08	Analog Percent Current	404.
C07	C08	Analog Percent Volts	404.
D07	D08	Analog Percent Power	404.
etc.	etc.	etc.	etc.

Since the configuration number only uses a number or a letter in each field (except for field 1) the A07 will then become an "A" for field 7 (see next page) when the full 16 digit configuration number is displayed.

	Type Number						Modification Number									
Field number: →	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Configuration number:	**66U**	**J**	**G**	**4**	**V**	**B**	**A**	**N**	**C**	**N**	**A**	**N**	**N**	**N**	**N**	**A, D**

Class Number	Type Number	Modification Number	Description
8829	66UJG4VB		15hp @ 460 V, Type 1 enclosure, variable torque, power circuit B
		A07	Analog speed meter
		C09	Start/stop push-button, speed pot & Hand auto switch
		A11	(B1 Option) 24 V I/O extension module
		A16	Red power on pilot light
		D16	Green run on pilot light

Remember: The drive controller nameplate and standard drawing documents will be identified by the configuration number only.

Identification System for Enclosed ALTIVAR 56

An enclosed drive configuration number uses Class, Type and Modification Numbers to identify the basic drive and optional devices. Fields 1 through 6 (see below) defines the basic type number, and the options are defined by modification field, field 7. The 7 digit configuration number that appears on all customer documents indicates the type and modification number, and deletes the field designation. This new 7 digit number will be compatible with future Square D product selectors and Q2C systems.

The configuration number for the enclosed drive breaks down into the following categories

Field number: →	1	2	3	4	5	6	7
Type number: →	**56U**		**G**				
	Controller Style	Horsepower 1 - 100	Enclosure, G fixed	Voltage 2, 3 or 4	Torque Application V or L	Power Circuits W, Y, & Z	Modifications

MCC DRIVES

Definition of Motor Control Center (MCC) Type Drive

A MCC type drive is very similar to an enclosed type drive. Square D still does the pre-engineering of the drive and enclosure. In the case of MCCs the Square D Seneca plant in South Carolina integrates the drive into the MCC. The one difference between the enclosed type and the MCC type is, that the drive is placed into a MCC bucket which is then integrated into the MCC structure.

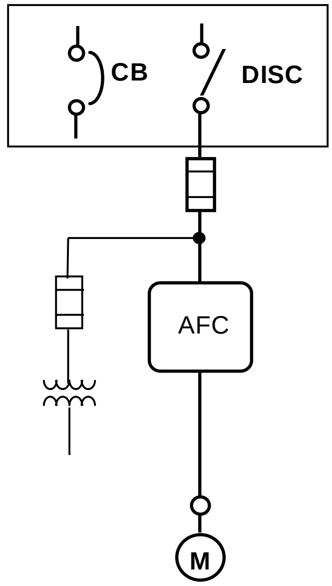
One of the considerations when installing a drive into a MCC is the temperature inside the cabinet. To control the temperature, Square D uses a thermal management system. This system circulates air across the heat sink of the drive itself. The advantage of this system is that the air that is used for cooling the drive is never mixed with the internal air of the enclosure or the drive structure. This system helps with keeping a constant temperature on the drive thus avoiding “hot spot” problems. The thermal management system also assists in reducing environment contaminants around the drive. Due to the thermal management system Square D does not have any restriction on the drive placement in the MCC structure.

Identifying if a user has a MCC type drive will be covered in the section on “How To Identify The Drive Type,” later in this chapter.

Which Square D AC Drives Can Be Used For MCC Type?

Of the drives covered in this course, the ALTIVAR 66 can be used for MCC type applications.

MCC Power Circuits



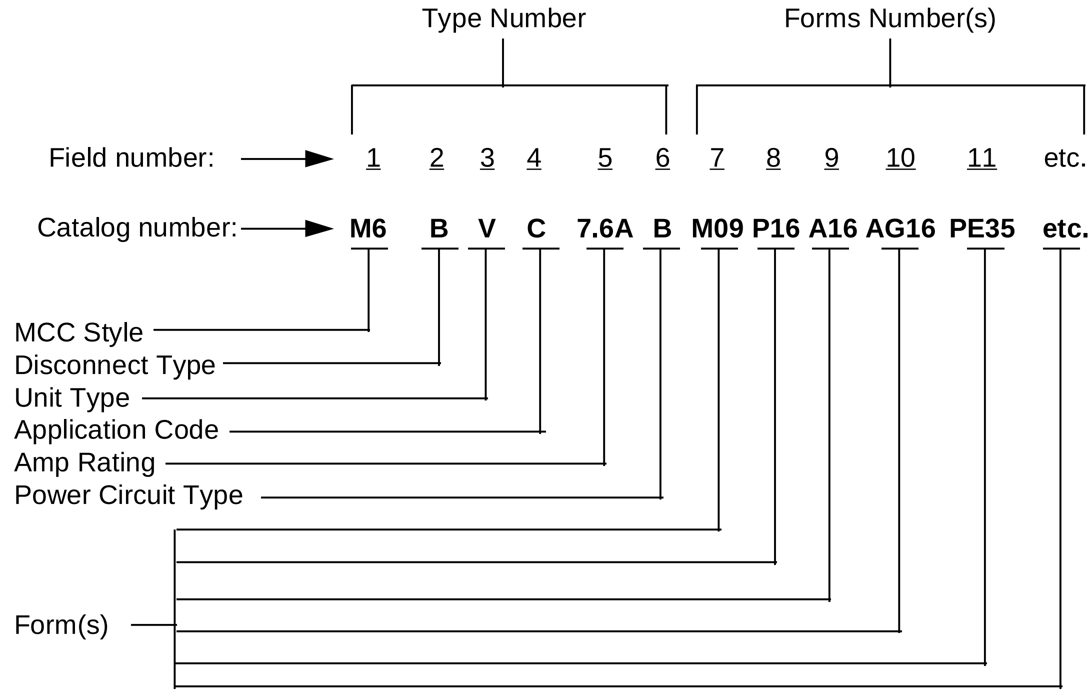
MCC power circuits are almost like enclosed drive power circuits. The user still needs to choose what power circuit configuration will be mounted into their enclosure. The user still has the same factors to take into consideration when choosing a power circuit. The one difference when working with MCC power circuits is that the MCC power circuits have different letter designations. Letters, B, C, U, E, G, AND H are used to differentiate the power circuits in an MCC. For a better understanding of how each power circuit is configured, see “MCC Power Circuits” in this chapter.

Identification System

A MCC with an ALTIVAR drive catalog number uses MCC style, Disconnect Type, Unit Type, Application code, Amperage rating, Power circuit, and Forms to identify the basic drive and optional devices. Fields 1 through 6 (see below) defines the basic type number, and the options are defined by forms numbers starting at field 7. The multi-digit catalog number that appears on all customer documents indicates the type and form number for the MCC.

	Type Number						Forms Number(s)					
Field number: →	1	2	3	4	5	6	7	8	9	10	11	etc.
Catalog number: →	**M6**	**B**	**V**	**C**	**7.6A**	**B**	**M09**	**P16**	**A16**	**AG16**	**PE35**	**etc.**

The catalog number for the MCC breaks down into the following categories



When generating a MCC catalog number entry you enter the entire form code for each of the form number fields. An example would be in the case of the form M09. Here you would enter in both the letter and the number. For additional information on the different configurations and options for MCCs with ALTIVAR drives reference the Model 6 Motor Control Center Price guide (Order Number 8998PL9202R10/96), Electronic Equipment section.

MCC Drive Selection

The following information provides some general selection information on the ALTIVAR 66 MCC drive packages from 1-200HP, 480V constant/variable torque or 1-75HP, 480V variable torque low noise. Drives are available at this time in NEMA Type 1, Type 1 gasketed enclosures, & Type 12 only. The drive units and options may be ordered as a “unit only device” and may be retrofitted in Model 6 or Model 5 MCCs. Non-standard drives are not available without a complete application, specification, and drawing review performed by your local Drives Specialist.

Note: When retrofitting a drive to an existing MCC remember to compare the dimensions of the new drive to the dimensions of the original drive. This is important because if the dimensions of the new drive are larger that the original drive, the new drive may not fit in enclosure space provided, and may require additional unit extender(s) for the additional space.

For Drive Selection:

1. Select all drives based on motor full load amperes. Horsepower is provided for convenience only.
2. Select the drive catalog number based on application (torque) type i.e. variable torque, constant torque or variable torque low noise. The drive will be factory programmed for the selected catalog number. If you need assistance in selecting the drive catalog number or reviewing the MCC specifications and drawings, or applications for the MCC, contact your local Drives Specialist.

3. The drive catalog numbers include a basic power circuit with a disconnect, current limiting fuses and drive controller. Select any optional contactors required for the application by referring to Table A, “Power Contactor Options” (Model 6 Motor Control Center Price guide, Order Number 8998PL9202R10/96, Electronic Equipment section) and changing the suffix letter of the drive catalog number.
4. Select any control circuit devices by referring to Table B, “Pilot Devices” (Model 6 Motor Control Center Price guide, Order Number 8998PL9202R10/96, Electronic Equipment section) and adding the form numbers to the catalog number.
5. Select any miscellaneous features such as line reactors or extra control VA by referring to Table C, “Miscellaneous Options” (Model 6 Motor Control Center Price guide, Order Number 8998PL9202R10/96, Electronic Equipment section) and adding the form numbers to the catalog number.

Various drive options can be provided to meet the user’s specific requirements. Many of those options or combinations of options may require additional mounting space or unit extender modifications. When assisting a user with drive options and space requirements, contact the Square D drives specialist, outside salesperson, or the MCC Technical Assistance Group (TAG) for additional information or assistance.

IDENTIFYING THE DRIVE TYPE

Identify The Drive Type

Users will usually be calling to order a drive for one of the following reasons.

- new installation
- replacement drive for existing installation or
- duplicate drive for another application or for the same application.

For replacement or duplicate installations the following procedure to assist you in determining whether the AC drive is mounted as an open type, enclosed type, or in a MCC.

1. Ask: Is the drive mounted in a Square D enclosure?
2. Use the following table to choose the procedure you want:

If the answer is . . .	**Then . . .**
Yes	1. Get class and type number from the enclosure data plate (usually, located inside of the door or the exterior of the enclosure). The number will start with the 8839 designator - that will help you determine the type and style of drive in the enclosure. **Note:** If MCC have user look inside the drive’s bucket for a data plate and locate the plant code (Ex. 046 = Seneca) and Factory Order number (F.O.). Then, cross reference the F.O. number back to the Square D drives specialist, outside salesperson or the TAG group in Seneca for complete drive specs. 2. Go to Step 3, below.

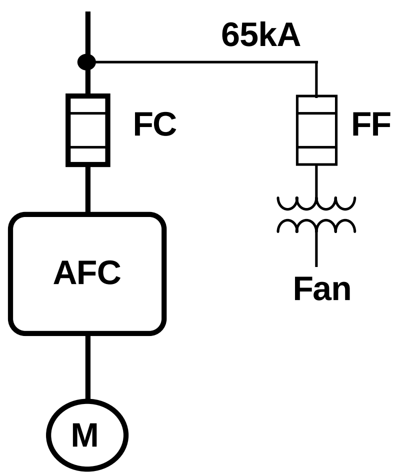
No	**Note:** Usually this will denote an open type drive. 1. Get class or product number from the name plate on the drive for the identification. **Example:** ATV66U41N4 2. Go to Step 3, below.
I can't find a name plate on the drive for identification	1. Have the user power up the drive - press the ESC key one time - this will give you the drive identification screen which will contain the product Identification number **Example:** ATV66U41N4 **Note**: This technique **will not** give you the option boards associated with the unit. You have to physically look in the drive and see if there is an option card installed. 2. Go to Step 3, below.

3. Using your normal order entry methods, place the order for the drive.

ENCLOSED POWER CIRCUITS

The following pages show you the different power circuit configurations offered for the different types of Class 8839 enclosures. These power circuits will become part of the part number when ordering the enclosure.

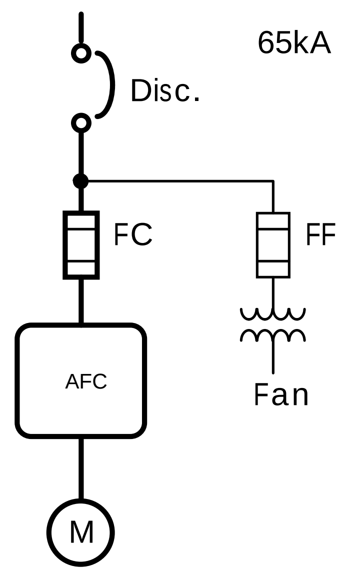
8839 Power Circuit "A"



FC = Fused Control
FF = Fused Fan
AFC = Adjustable Frequency Control Drive

- Lowest Economy-Optimized for NEMA 1 & 12 Enclosure
- No Disc Device or Bypass
- UL 508C listed for 65 kAIC
- Current limiting line fuses
- Control Transformer for Vent Fans

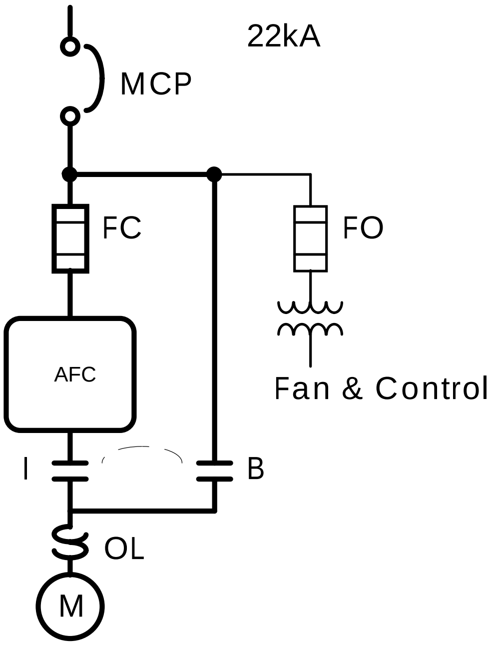
8839 Power Circuit "B"



Disc. = Disconnect
FC = Fused Control
FF = Fused Fan
AFC = Adjustable Frequency Control Drive

- Moderate Economy-Optimized for NEMA 1 &12 Enclosure
- Includes Molded Case Disconnect Switch
- UL 508C listed for 65 kAIC
- Current limiting line fuses
- Control Transformer for Vent Fans

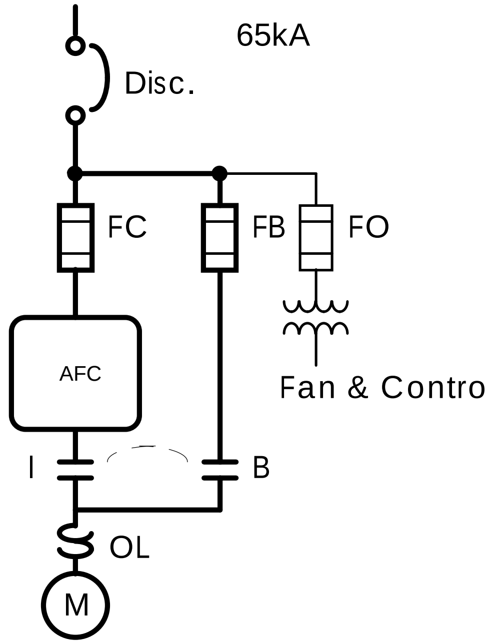
8839 Power Circuit "C"



MCP = Motor Circuit Protector
FC = Fused Control
FO = Fused Option
AFC = Adjustable Frequency Control Drive
I = Isolation Contactor
B = Bypass Contactor
OL = Overload

- Lowest Economy-Integrated Iso & Bypass Contactors for NEMA 1 & 12 Enclosure
- Includes MAG-GARD Breaker
- UL 508C listed for 22 kAIC
- Current limiting line fuses
- Control Transformer for Vent Fans

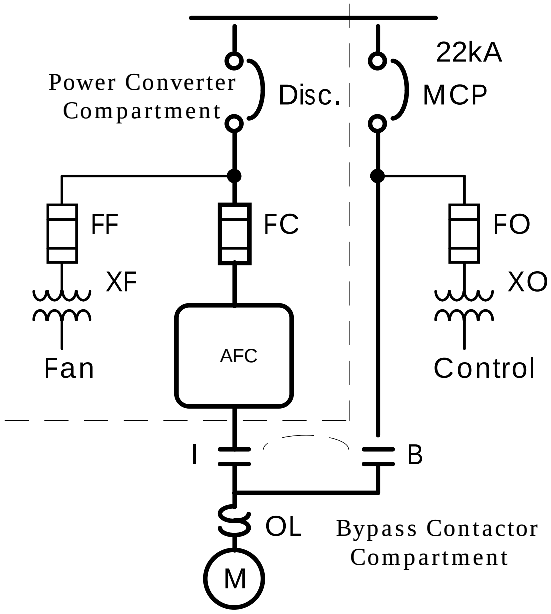
8839 Power Circuit "D"



Disc. = Disconnect
FC = Fused Control
FB = Fused Bypass
FO = Fused Option
AFC = Adjustable Frequency Control Drive
I = Isolation Contactor
B = Bypass Contactor
OL = Overload

- Moderate Economy-Integrated Iso/Bypass Contactors for NEMA 1 & 12 Enclosure
- Includes Molded Case Switch
- UL 508C listed for 65 kAIC
- Current limiting line fuses
- Control Transformer for Vent Fans

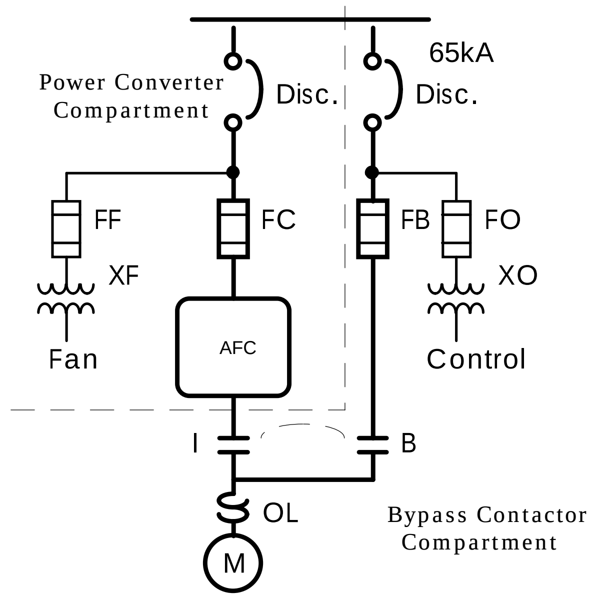
8839 Power Circuit "E"



Disc. = Disconnect
MCP = Motor Circuit Protector
FF = Fused Fan
FC = Fused Control
XF = Transformer Fan
XO = Transformer Option
FO = Fused Option
AFC = Adjustable Frequency Control Drive
I = Isolation Contactor
B = Bypass Contactor
OL = Overload

- Lowest Economy-Barrier Iso/Bypass Contactors NEMA 1 & 12 Enclosure
- Includes Molded Case switch & MAG-GARD® Breaker
- UL 508C listed for 22 kAIC
- Current limiting line fuses
- Includes 2-Control Transformers

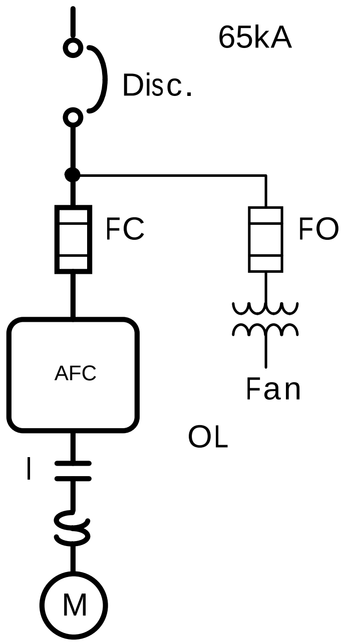
8839 Power Circuit "F"



Disc. = Disconnect
MCP = Motor Circuit Protector
FF = Fused Fan
FC = Fused Control
FB = Fused Bypass
XF = Transformer Fan
XO = Transformer Option
FO = Fused Option
AFC = Adjustable Frequency Control Drive
I = Isolation Contactor
B = Bypass Contactor
OL = Overload

- Moderate Economy-Barrier Iso/Bypass Contactors NEMA 1 & 12 Enclosure
- Includes Two Molded Case Switches
- UL 508C listed for 65 kAIC
- Current limiting line fuses
- Includes 2-Control Transformers

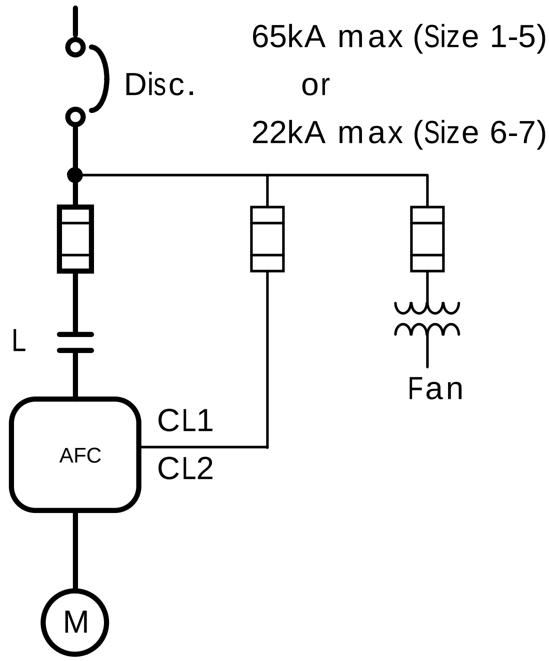
8839 Power Circuit "G"



Disc. = Disconnect
FC = Fused Control
FO = Fused Option
AFC = Adjustable Frequency Control Drive
I = Isolation Contactor
OL = Overload

- Moderate Economy-Integrated Output Isolation Contactor for NEMA 1 & 12 Enclosure
- Includes Molded Case Switch
- UL 508C listed for 65 kAIC
- Current limiting line fuses
- Control Transformer for Vent Fans

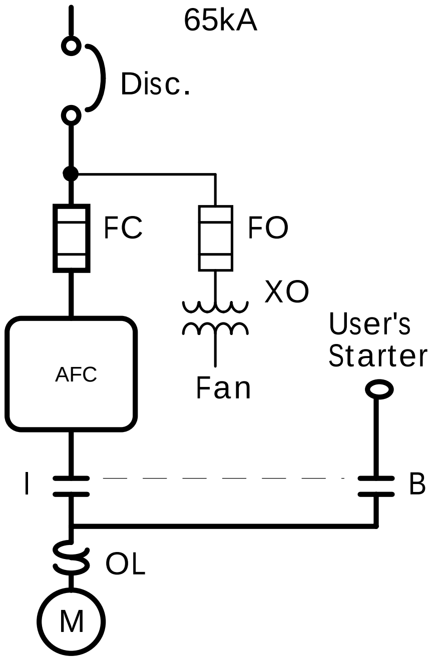
8839 Power Circuit "H"



Disc. = Disconnect
L = Line Contactor
AFC = Adjustable Frequency Control Drive
CL1 = Control Line 1
CL2 = Control Line 2

- Moderate Economy-Integrated Input Line Isolation Contactor NEMA 1 & 12 Enclosure
- Includes Molded Case Switch
- UL 508C listed for 65 kAIC
- Current limiting line fuses
- Control Transformer for Vent Fans

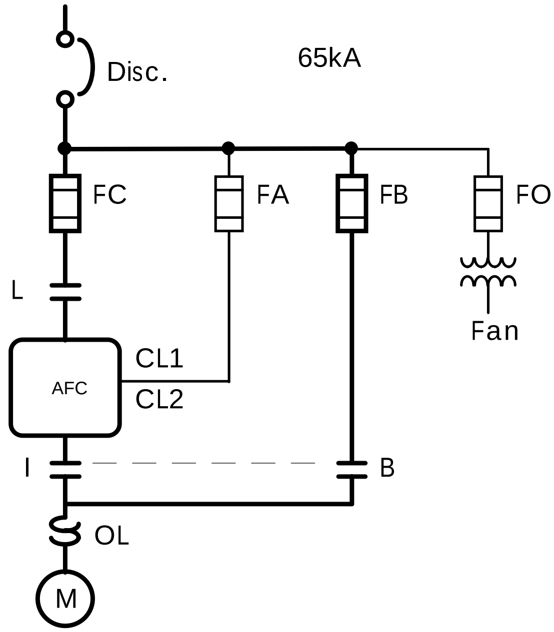
8839 Power Circuit "I"



Disc. = Disconnect
FC = Fused Control
XO = Transformer Option
FO = Fused Option
AFC = Adjustable Frequency Control Drive
I = Isolation Contactor
B = Bypass Contactor
OL = Overload

- Moderate Economy-Integrated Input Line Isolation Contactor NEMA 1 & 12 Enclosure
- Includes Molded Case Switch
- UL 508C listed for 65 kAIC
- Current limiting line fuses
- Control Transformer for Vent Fans

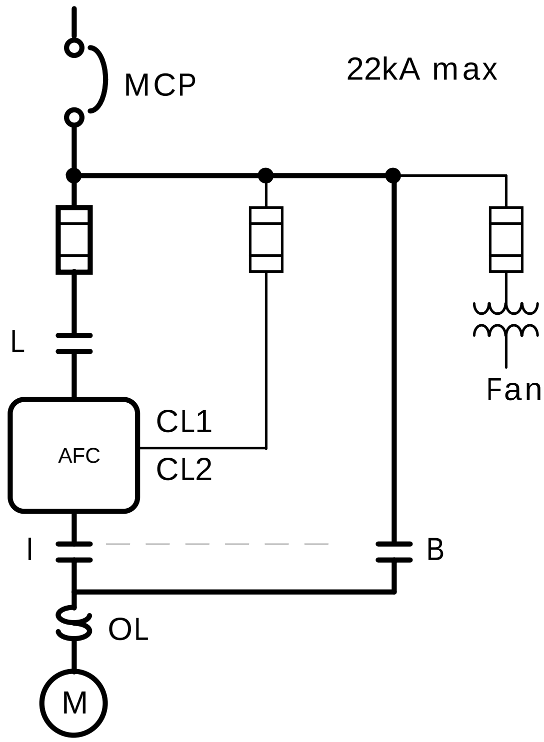
8839 Power Circuit "J"



Disc. = Disconnect
FC = Fused Control
FA = Fused
FB = Fused Bypass
FO = Fused Option
L = Line Contactor
AFC = Adjustable Frequency Control Drive
I = Isolation Contactor
B = Bypass Contactor
OL = Overload

- Moderate Economy-Integrated Input Line and Iso/Bypass Contactors for NEMA 1 & 12
- Includes Molded Case Switch
- UL 508C listed for 65 kAIC
- Current limiting line fuses
- Control Transformer for Vent Fans

8839 Power Circuit "K"



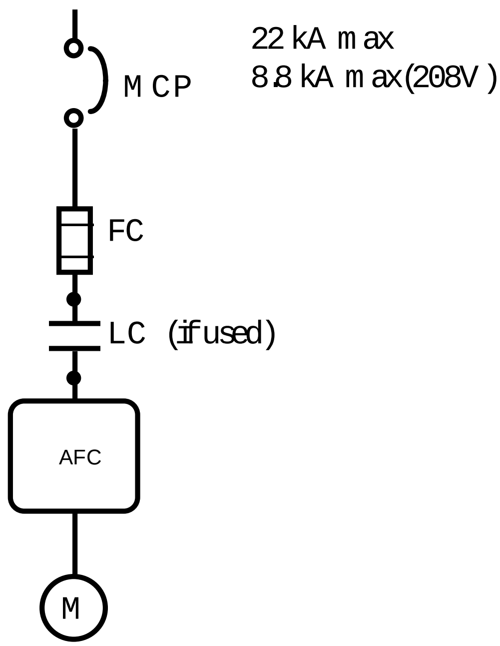
MCP = Motor Circuit Protector
L = Line Contactor
CL1 = Control Line 1
CL2 = Control Line 2
AFC = Adjustable Frequency Control Drive
I = Isolation Contactor
B = Bypass Contactor
OL = Overload

- Lowest Economy-Integrated Input Line and Iso/Bypass Contactors for NEMA 1 & 12
- Includes MAG-GARD® Breaker
- UL 508C listed for 22 kAIC
- Current limiting line fuses
- Control Transformer for Vent Fans

ALTIVAR 56 Power Circuits

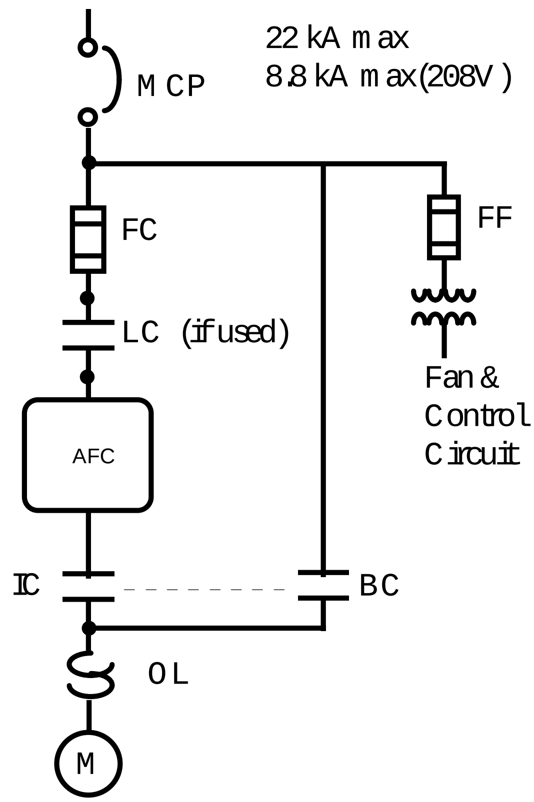
The following pages show you the different power circuit configurations offered for the different types of Class 8839 ATV56 enclosures. These power circuits will become part of the part number when ordering the enclosure.

Combination Package Power Circuit



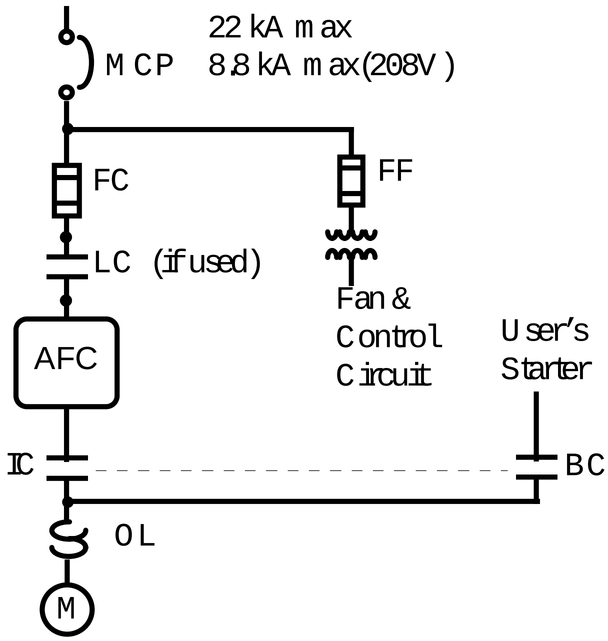
MCP = Motor Circuit Protector
FC = Fused Control
LC = Line Contactor
AFC = Adjustable Frequency Control Drive

Bypass Package Power Circuit



MCP = Motor Circuit Protector
FC = Fused Control
LC = Line Contactor
IC = Isolation Contactor
BC = Bypass Contactor
OL = Overload

Remote Starter Bypass Package Power Circuit

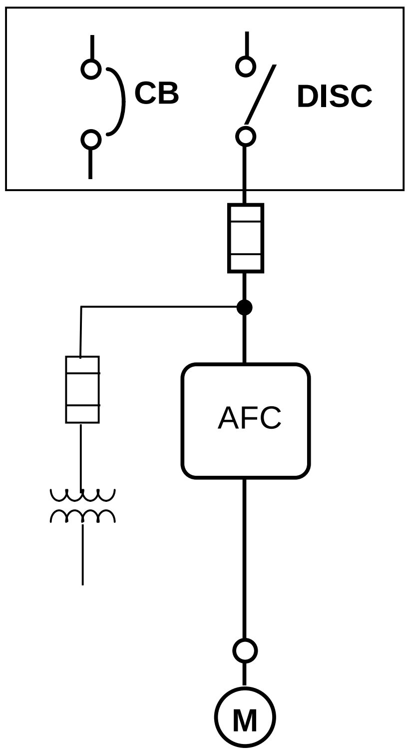


MCP = Motor Circuit Protector
FF = Fused Fan
FC = Fused Control
LC = Line Contactor
IC = Isolation Contactor
BC = Bypass Contactor
OL = Overload

MCC POWER CIRCUITS

Likewise, the following pages show you the different power circuit configurations offered for the different types of MCC enclosures. These power circuits will become part of the part number when ordering the MCC.

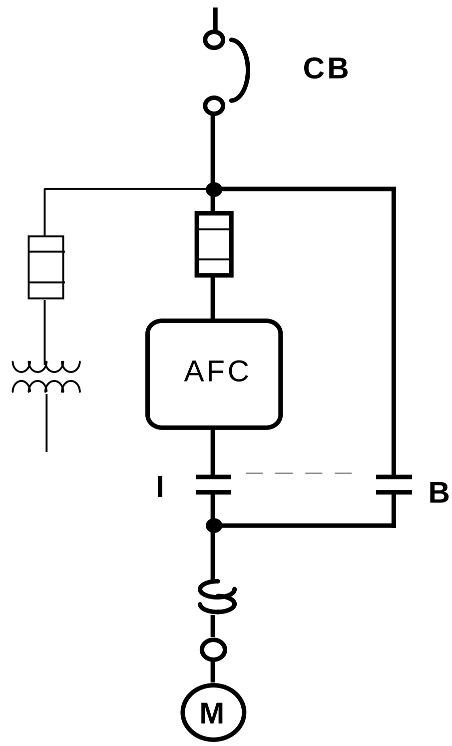
8998 Power Circuit "B"



CB = Circuit Breaker
DISC = Disconnect
AFC = Adjustable Frequency Control Drive

- Moderate Economy-Optimized for NEMA 1 &1A Enclosure
- Disconnect device - FS or CB
- UL 845 listed for 65 kAIC
- Current limiting line fuses
- Control Transformer for Vent Fans

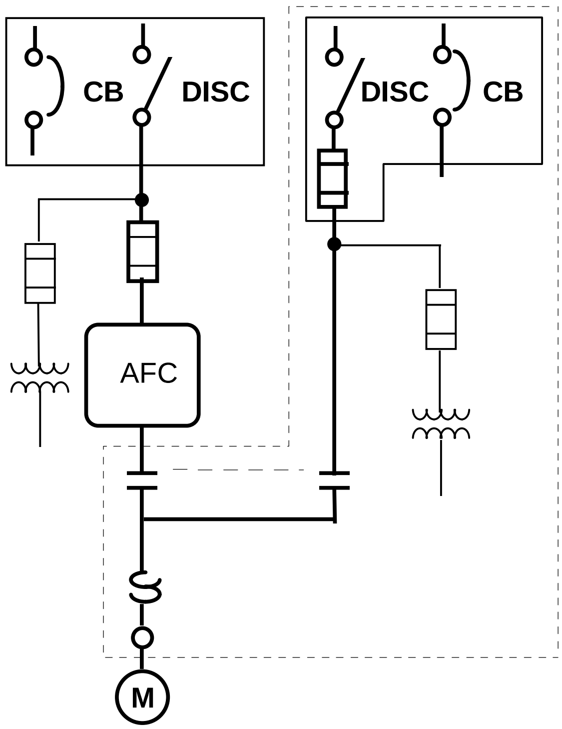
8998 Power Circuit "C"



CB = Circuit Breaker
AFC = Adjustable Frequency Control Drive
I = Isolation Contactor
B = Bypass Contactor

- Moderate Economy-Integrated Bypass for NEMA 1 &1A Enclosure
- Disconnect device - CB only
- UL 845 listed for 65 kAIC
- Current limiting line fuses
- Control Transformer for Vent Fans

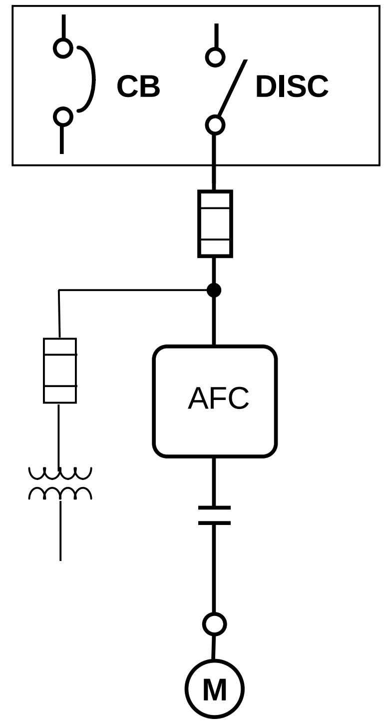
8998 Power Circuit “U & E”



CB = Circuit Breaker
DISC = Disconnect
AFC = Adjustable Frequency Control Drive

- Moderate Economy-Barriered Bypass for NEMA 1 &1A Enclosure
- Disconnect device - FS or CB
- “U” Barriered - NEMA cont.
- “E” Barriered Application Rated (Compac)
- UL 845 listed for 65 kAIC
- Current limiting line fuses
- Control Transformer for Vent Fans

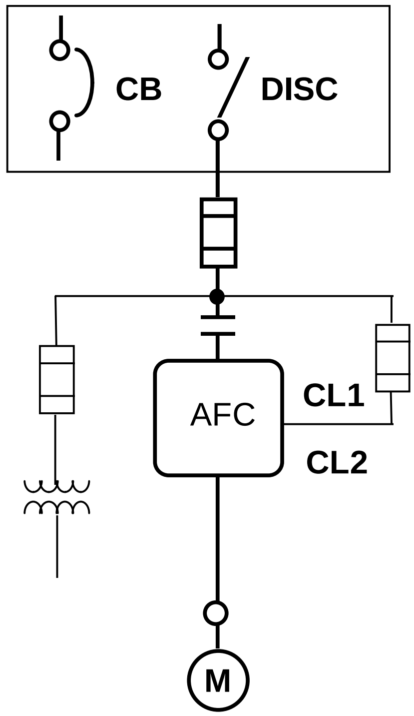
8998 Power Circuit “G”



CB = Circuit Breaker
DISC = Disconnect
AFC = Adjustable Frequency Control Drive

- Moderate Economy-Output Contactor for NEMA 1 & 1A Enclosure
- Disconnect device - FS or CB
- UL 845 listed for 65 kAIC
- Current limiting line fuses
- Control Transformer for Vent Fans

8998 Power Circuit "H"



CB = Circuit Breaker
DISC = Disconnect
AFC = Adjustable Frequency Control Drive
CL1 = Control Line 1
CL2 = Control Line 2

- Moderate Economy-Input Contactor for NEMA 1 &1A Enclosure
- Disconnect device - FS or CB
- UL 845 listed for 65 kAIC
- Current limiting line fuses
- Control Transformer for Vent Fans
- Auto Diagnostics

SELF CHECK QUESTIONS AND EXERCISES

Use the information in this chapter to answer the following:

1. A user called and is looking for a replacement drive that they installed into their own cabinet, what kind of drive type is the client looking for? ____________________________________

____

2. When retrofitting a drive to an existing enclosure is it important to be concerned about the physical dimensions of the drive?

____

Why?

____

3. What cooling system does Square D use when installing a drive into a Motor Control Center?

____

4. The definition of an open drive type is?

____

____

SELF CHECK ANSWERS

Use the information in this chapter to answer the following:

1. A user called and is looking for a replacement drive that they have installed in their own cabinet, what kind of drive type is the client looking for? The user has an open type drive

2. When retrofitting a drive to an existing enclosure is it important to be concerned about the physical dimensions of the drive? Yes

Why?

This way you can verify that the drive will fit correctly into the user's enclosure

3. What cooling system does Square D use when installing a drive into a Motor Control Center?

Thermal Management System

4. The definition of an open drive type is?

An open type drive is where the user buys the drive as a component piece, to use as is or build into their own process or machine.

Chapter 5 - Helping Customers

LEARNING OBJECTIVES

The participant will:

- Be able to route a customer's drive question to the local Square D sales office for assistance.
- Be able to gather basic customer drive application data for use by Square D personnel in sizing a drive or selecting the appropriate drive product.

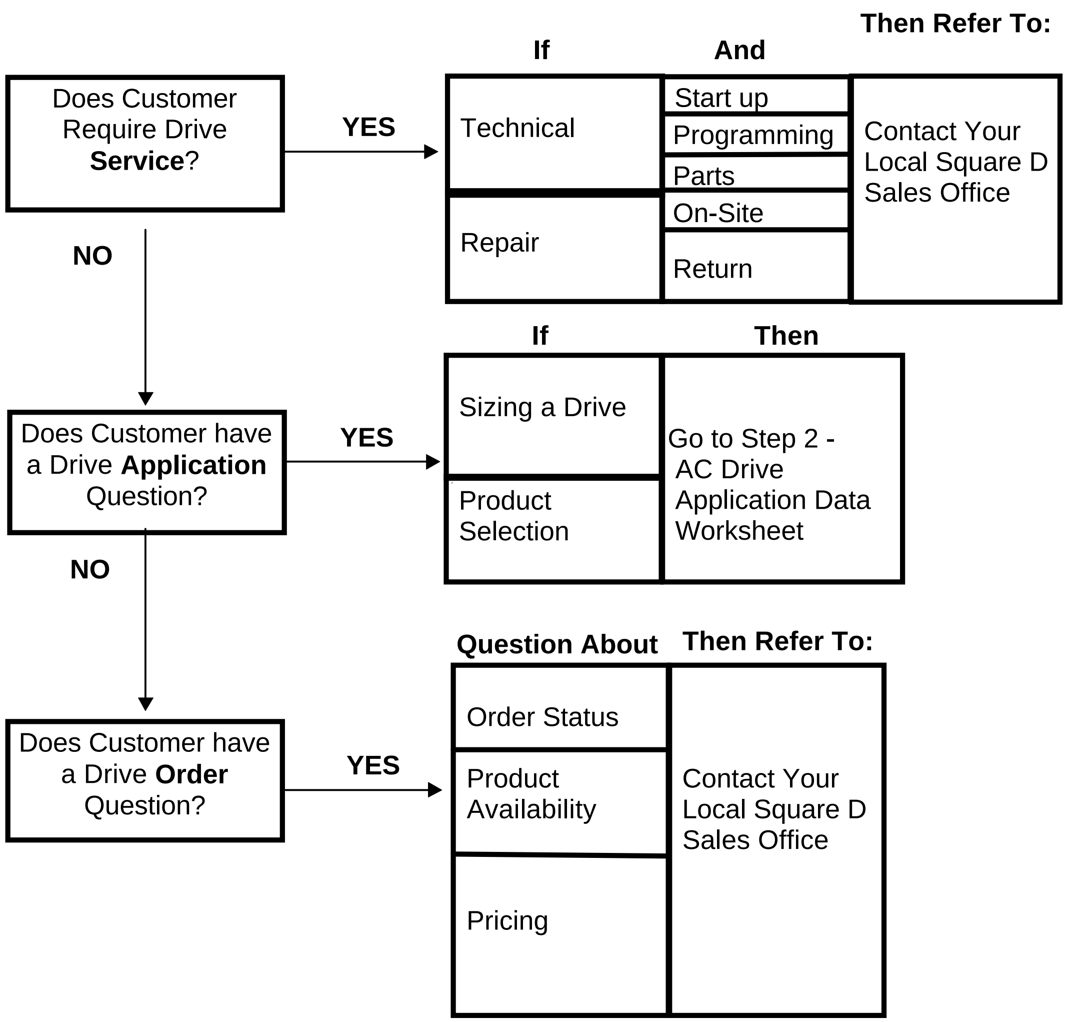
HELPING CUSTOMERS WITH AC DRIVE INQUIRIES

The preceding chapters have given you training in the fundamentals of AC motors, fundamentals of AC drives, and introduced Square D AC drive products and AC drive types. The main objective of this training has been to remove some of the mystery surrounding AC drives and prepare you for further, more in depth training on AC drives if that is your desire. With the knowledge you have now you can provide a service to your customers by answering as many drive questions as you can, and by gathering vital application information from them to be passed on to those more experienced in handling AC drive application and selection issues. A glossary of terms is provided to assist you in quickly getting information about unfamiliar terms or concepts.

The following job aids will help you to gather important customer drive application information and to refer your customers to the proper persons to handle more technical drive issues.

Customer calls with an AC Drive inquiry:

Step 1 Use the following job aid to determine what drive service the customer requires:



<u>Step 2</u> Complete the following AC Drive Application Worksheet

Try to gather as much information as you can from the customer regarding their application using this worksheet. After completing the worksheet provide a copy of it to the person who will be handling the customer's application question. You may want to make additional copies of this worksheet.

AC DRIVE APPLICATION WORKSHEET

CUSTOMER DATA:

Company Name: ____ Date: ________________

Address: ____

____

Contact: _____________________________________ Phone: (______)__________________

Fax: (______) ________________________________

MOTOR DATA:

NEMA Motor Type:

NEMA A ☐ NEMA B ☐ NEMA C ☐ NEMA D ☐

Synchronous Reluctance ☐ Other ☐

If "Other", describe: ____

Motor Nameplate Data:

HP ________ Voltage 3 PH ______ Hz ______ Poles _____ FLA ______ LRA _____

RPM ______ Enclosure Type _____________ Frame ___________ Mounting _________

Insulation Class _____________________________ Service Factor ___________________

Gear Box Type ____________________ Ratio __________________

APPLICATION DATA:

Application (Type of machinery or equipment) ____

____

Type of Load (if unsure, see - Table 1: Application Characteristics of Typical Loads):

Constant Torque ______ Constant HP _______ Variable Torque ______ Impact ______

Other ____

Measured Load Running __________ Amps Peak Load _____________ Amps

APPLICATION DATA (CONT)

Duty Cycle Per Hour ____

If Applicable, Create Time Vs Load Graph ____

Speed Range Required ____________ Minimum Speed to _____________ Maximum Speed

Is High Breakaway Torque Required? YES ☐ NO ☐

Speed Regulation Required? YES ☐ NO ☐ If Yes, Specify ________ % of Base Speed

Is Acceleration or Deceleration Time Critical? YES ☐ NO ☐

If Yes, Answer Questions Below:

Load Inertia: _________________ Lb. Ft.^{2}

Acceleration Requirement: Minimum _______ seconds Maximum _______ seconds

Deceleration Requirement: Minimum _______ seconds Maximum _______ seconds

ENVIRONMENT:

Input Line _________ Volts ± __________ % ___________ Phase __________ Hertz

Drive Controller Enclosure Type: Open Type ☐ NEMA 1 ☐ NEMA 12 ☐

Other (Specify): ____

Temperature (Ambient) ____________ °C (°F) to _______________ °C (°F)

Altitude - If Drive Controller Is Greater Than 3300 Ft. Above Sea Level, Specify: __________

Are There Any Other Conditions Or Data Which May Effect Drive Sizing? If Yes, Please Specify:

____

CONTROL:

Indicate Type of Control Scheme Required:

Start	_______	Hand-Auto	_______
Stop	_______	Run-Jog	_______
Start/Stop Pushbutton	_______	Hand-OFF-Auto	_______
Forward-Reverse	_______	Power ON Pilot Light	_______

Other types of control not listed above

____

Speed Reference by Manual Speed Potentiometer _______

Fail Pilot Light _______

APPLICATION CHARACTERISTICS OF TYPICAL LOADS

This table lists the typical load characteristics - use it as a guideline only. If you have a question about the type of load for an application, confirm this information with the machinery manufacturer.

Table 1: Application Characteristics of Typical Loads

Application	Load	Breakaway Torque	Application	Load	Breakaway Torque
Agitators			Machines		
Liquid	*VT	Moderate	Boring	CT	Moderate
Slurry	*VT	Moderate	Bottling	CT	Moderate
Blowers			Milling	*CHP	Moderate
Centrifugal	VT	Low	Mills		
Positive Displacement	CT	Low (Unloaded)	Rolling	*CT	Moderate
Calenders	CT	Low	Rubber	*CT	Moderate
Card Machines	CT	Moderate	Mixers		
Centrifuges	CT	Moderate	Chemical	CT	High
Chippers	*CT	High	Dough	CT	High
Compressors			Slurry	CT	High
Axial - Centrifugal	VT	Low	Planers	CT	Moderate
Reciprocating	*CT	Moderate	Plows - Conveyor	CT	Moderate
Rotary	CT	Moderate	Presses		
Conveyors			Printing	CT	Moderate
Belt	CT	Moderate	Punch	*CT	Moderate
Screw	*CT	High	Pullers - Car	CT	Moderate
Shaker	*CT	Moderate	Pumps		
Cranes			Centrifugal	VT	Low
Bridge	CT	Moderate	Positive Displacement	CT	Moderate
Trolley	CT	Moderate	Slurry	CT	High
Hoist	CT	Moderate	Roll Benders	CT	Moderate
Crushers	*CT	High	Sanders	CT	Low
Drill Presses	CHP	Moderate	Saws	*CT	Moderate
Elevators	CT	Moderate	Shakers	*CT	High
Extruders	CT	Moderate	Shears	*CT	Low
Fans - Centrifugal	VT	Low	Tension Drives	CHP	Moderate
Frames - Spinning	CHP	Low	Tool Machines	CHP	Moderate
Grinders	CHP	Moderate	Walkways	CT	Low
Kilns	CT	High	Winches	CT	Moderate
Looms	CT	Moderate	Winders	CHP	Moderate
Lathes	*CHP	Moderate	Washers	CT	Moderate

VT = Variable Torque
CT = Constant Torque
CHP = Constant Horsepower
* = Potential Impact Load

High = Greater than 150% Torque
Moderate = Between and Including 100% to 150% Torque
Low = Less than 100% Torque

Step 3 - After completing the Application Data Worksheet, call your local Square D sales office and relay the customer's question as well as the application information you have gathered to either the Square D drives specialist or outside salesperson.

APPENDIX A

SELF ASSESSMENT STUDY GUIDE ANSWERS

SELF ASSESSMENT STUDY GUIDE ANSWERS

Select the best answer:

1. The armature of a motor consists of __D__ .
- **A.** the housing and rotor
- **B.** the shaft and stator
- **C.** the stator and housing
- **D.** the shaft and rotor

2. The magnetic fields of the stator and rotor are changed according to the __B__ .
- **A.** the current applied to the motor
- **B.** frequency of the AC voltage applied to the motor
- **C.** the frequency of the current applied to the motor
- **D.** the wattage applied to the motor

3. The speed of the rotor is determined by the __B__ .
- **A.** the current applied to the motor
- **B.** frequency of the AC voltage applied to the motor
- **C.** the frequency of the current applied to the motor
- **D.** the wattage applied to the motor

4. The difference between a motor's synchronous and actual rotor speed is called the __C__ .
- **A.** Variable torque
- **B.** Dynamic speed
- **C.** Slip
- **D.** Magnetic flux

5. The torque a motor produces is directly related to __A__ .
- **A.** the current applied to the motor
- **B.** frequency of the AC voltage applied to the motor
- **C.** the frequency of the current applied to the motor
- **D.** the wattage applied to the motor

6. The maximum torque that a motor can produce is called: __C__ .
- **A.** Full load torque
- **B.** Constant torque
- **C.** Breakdown torque
- **D.** Overload toque

7. A motor's service factor indicates the: __D__ .
- **A.** Approximate life expectancy of the motor if applied within the rated nameplate parameters
- **B.** The NEMA rating of the motor which is comparable to the torque performance of the motor.
- **C.** Electrical power supplied to the motor.
- **D.** Overloads which may be carried by the motor without exceeding the maximum temperature recommended for the insulation

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If you answered questions 1 - 7 correctly you may skip the training presented in Chapter 1 - AC Motor Fundamentals

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8. Match the components of an AC drive with their function:

__**B**__ Inverter	**A.** This section smoothes rectified DC before it goes to the next section.
__**A**__ DC bus filtering	**B.** This section changes DC into an adjustable frequency synthetic AC
__**C**__ Converter	**C.** This section changes 60 Hz AC power into DC

9. The difference between a soft start and an AC drive is: __**A**__ .

A. That the soft start reduces voltage and current at startup
B. That an AC drive controls motor startup by reducing startup torque.
C. That a soft start can be used in place of an AC drive
D. All of the above
E. None of the above

10. Maintaining the volts per Hertz ratio is necessary because: __**B**__ .

A. In order to accurately measure a given motor's speed then the ratio of both the voltage and frequency must be maintained.
B. When a motor is running at less than full speed maintaining this ratio provides a method of keeping the magnetic flux constant, thus producing full load-torque.
C. The voltage and frequency coming from the power generating station may varies in both voltage and frequency.
D. The horsepower of the motor is dependent upon this ratio.

11. With a constant torque load: __**A**__ .

A. Torque remains the same as the speed changes.
B. Horsepower varies inversely with the speed.
C. Torque remains the same as the current changes.
D. All of the above.

If you answered questions 8 - 11 correctly you may skip the training presented in Chapter 2 - AC Drive Fundamentals

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12. __**B**__ AC drives can only be ordered as replacements to existing equipment.

A. ALTIVAR
B. OMEGAPAK
C. ALTIVAR and OMEGAPAK
D. There are no limited offerings with AC drives

13. The complete ALTIVAR family consists of **D** .

A. ALTIVAR 16, 26, 55, and 67
B. ALTIVAR 8803, 8804, 16, and 18
C. ALTIVAR 8803 and 8804
D. ALTIVAR 16, 18, 56, and 66

14. The ALTIVAR drives meet **A** standards.

A. ISO 9000 series, and UL, CSA, IEC, VDE
B. UL, CSA, IEC, VDE
C. ISO 9000, ISO 3000 series, and UL, VDE
D. ISO 9007 series, and UL, CSS, ICC, VDE

15. **C** are the major components for Dynamic Braking.

A. Jumper J-12 to switch a resistor circuit in and out, and a separately mounted brake
B. A separately mounted semi-conductor circuit and resistor R-7
C. A power semi-conductor to switch resistor circuit in and out, and a separately mounted braking resistor
D. A power semi-conductor to switch resistor circuit in and out, and three separately mounted braking resistors

If you answered questions 12 - 15 correctly you may skip the training presented in Chapter 3 - Square D AC Drive Products

16. An open type drive is bought as **A** .

A. As a component piece
B. As a total Square D enclosure
C. As a total Square D MCC
D. All of the above

17. **C** drive(s) can be used for open type applications.

A. OMEGAPAK 8803 and 8804
B. ALTIVAR 16, 18
C. ALTIVAR 16, 18, 56, and 66
D. ALTIVAR 16, 18, 56, 66, and OMEGAPAK 8803 and 8804

18. Enclosed type drives are manufactured at the **B** .

A. Square D Raleigh plant in North Carolina
B. Square D Columbia plant in South Carolina
C. Square D Seneca plant in South Carolina
D. Square D Oxford plant in Ohio

19. __B__ drive(s) can be used for MCC applications.

A. OMEGAPAK 8803
B. ALTIVAR 66
C. ALTIVAR 16
D. ALTIVAR 56

20. The MCC drive packages can be from __D__ .

A. 1-50HP, 220V constant/variable torque or 1-25HP, 480V variable torque low noise
B. 1-800HP, 240V constant/variable torque or 1-75HP, 400V variable torque high noise
C. 1-50HP, 480V constant/variable torque or 1-250HP, 480V variable torque no noise
D. 1-200HP, 480V constant/variable torque or 1-75HP, 480V variable torque low noise

21. Enclosed Type drives are offered in __A__ .

A. NEMA Type 1 and Type 12 enclosures
B. NEMA Type 1, Type 3, and Type 12 enclosures
C. NEMA Type 12 enclosures
D. NEMA Type 4 and Type 12 enclosures

If you answered questions 16 - 21 correctly you may skip the
training presented in Chapter 4 - AC Drive Characteristics & Types

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GLOSSARY
OF
TERMS

GLOSSARY OF TERMS

120/240 Voltage System	Most commonly used in residential applications, by using this (single phase 3 wire) system 120 volts is available between phase and neutral and 240 volts is available phase-to-phase.
240 Volt Delta system:	This is an uncommon (regional) system used in light industrial applications. This (3 phase 3 wire) system provides 240 volts phase to phase. The NEC requires most of these systems to be grounded hence the name “Grounded B phase”. This system requires careful selection and installation of electrical equipment, particularly circuit breakers and motor controllers.
240/120 Delta System	Most commonly referred to as a “Wild Leg” system. (3 phase 4 wire) 240 volts is available between phases and 120 volts is available between two of the phases and the neutral which is grounded (usually the A and C phases). It should be noted that between the B phase and ground 208 volts is available.
208Y/120 Volt Wye System	Common system for commercial applications. By using this (3 phase 4 wire) system: 120 volts, for lighting and receptacle loads, is available between any phase and neutral; and 208 volts, for motors and heating loads, is available phase to phase.
480 Volt Delta system:	Very common system in large industrial applications. This (3 phase 3 wire) system is usually installed ungrounded and requires maintenance by “qualified persons”. Electrical equipment installed on this system must be rated 480V phase to ground as well as phase to phase.
480Y/277 Volt Wye System:	The most common system in large commercial and industrial applications. By using this (3 phase 4 wire) system: 277 volts, for lighting loads, is available between any phase and neutral; and 480 volts, for motors and heating loads, is available phase to phase.
AA (med. voltage transformers)	Abbreviation for Air-To-Air. Self-cooled by convection and conduction as it applies to a dry-type transformer, i.e. the heat transfer path.

Adjustable Speed	The concept of varying the speed of a motor, either manually or automatically. The desired operating speed (set speed) is relatively constant regardless of load.
Adjustable Speed Drive (Electrical)	The adjustable speed drive is comprised of the motor, drive controller and operator's controls (either manual or automatic).
AIC	Ampere interrupting capacity. See AIR or ampere interrupting rating.
AIR	Ampere Interrupting rating. The highest current at rated voltage that a circuit breaker is intended to interrupt under standard test conditions.
Alternating current	This is the most common type of current used today. In the United States, all electricity is generated as alternating current. It is called alternating current because first the current flows in one direction then it will flow in the opposite direction and so on. The current alternates between two opposite directions. (It is often represented by a side-ways "s") Alternating current is used in homes for lighting, heating, cooking, and operating appliances. Industry uses it primarily to operate motors but also for lighting and equipment operation. The abbreviation for alternating current is "AC".
Ambient Noise Level	The noise level of the surrounding area measured in decibels.
Ambient Temperature	Temperature of the surrounding atmosphere into which the heat of any electrical product is dissipated.
Ambient Temperature Rating	Temperature at which the continuous current rating (handle rating) of a circuit is based; the temperature of the air immediately surrounding the circuit breaker that can affect the thermal (overload) tripping characteristics of a thermal-magnetic circuit breaker. Electronic trip circuit breakers, however, are insensitive to normal (-5^{o} to 50^{o} C) ambient conditions. UL standard 489 listed circuit breakers have an ambient temperature rating of 40^{o} C.
ANSI	American National Standards Institute
ANSI 49	Shade of gray paint color. Standard means of describing paint color with the number indicating the percentage of reflected light. (ANSI 0 would be black, ANSI 100, totally reflective).

Armature (motor)	An assembly composed of the rotor and the shaft.
ASTM	American Society for Testing Materials
ATC (m.v. transformers)	Air terminal compartment (i.e., air-filled as opposed to oil-filled). Space in which to terminate cable connections to a transformer.
Automatic Protection Circuit	A device which automatically (no human action needed) disconnects power. For an example, a circuit breaker is both a manual and automatic device. A person can manually open a circuit breaker or it can automatically open if it senses an overcurrent condition.
Axis	A principle direction along which movement of the tool or workpiece occurs. The term axis also refers to one of the reference lines of a coordinate system.
Back of a Motor	The back of a motor is the end which carries the coupling or driving pulley (NEMA). This is sometimes called the drive end (D.E.) or pulley end (P.E.).
Bandwidth	Generally, frequency range of system input over which the system will respond satisfactorily to a command.
Base Speed	Base speed is the manufacturer's nameplate rating where the motor will develop rated HP at rated load and voltage. With DC drives, it is commonly the point where full armature voltage is applied with full rated field excitation. With AC systems, it is commonly the point where 60 Hz is applied to the induction motor.
Bearing (Ball)	A "ball" shaped component that is used to reduce friction and wear while supporting rotating elements. For a motor, this type of bearing provides a relatively rigid support for the output shaft.
Bearing (Roller)	A special bearing system with cylindrical rollers capable of handling belted load applications, too large for the output shaft.
BIL	Basic Insulation Level. A specific insulation level expressed in kilovolts of the crest value of a standard lightning impulse.
Bolt-on Connection (motor control centers)	Interior device is cable-connected directly to the horizontal bus by means of bolted connection.

Branch Circuit

An electrical path which connects to the main electrical path. If a branch is disconnected from the main branch only the load connected to that branch looses power. All other branches are not affected by the disconnection.

Branch Circuit Breaker

Switch which is connected to the main circuit path and the first load in the branch. It is used to turn off power to that branch circuit.

Breaking

Breaking provides a means of stopping an AC or DC motor and can be accomplished in several ways:

A. *Dynamic Braking (DC Drives)* --- slows the motor by applying a resistive load across the armature leads after disconnection from the DC supply. This must be done while the motor field is energized. The motor then acts as a generator until the energy of the rotating armature is dissipated. This is not a holding brake.

Dynamic Braking (AC Drives) --- Since AC motors do not have separate field excitation, dynamic braking is accomplished by continuing to excite the motor from the drive. This causes a regenerative current to the drive's DC Intermediate Bus Circuit. The Dynamic Brake resistors are then placed across the DC bus to dissipate the power returned. The brake resistor is usually switched by a transistor or other power switch controlled by the drive.

B. *Regenerative Braking* --- is similar to Dynamic Braking, but is accomplished electronically. The generated power is returned to the line through the power converter. It may also be dissipated as losses in the converter (within its limitations).

C. *Motor Mounted or Separately Mounted Brake* --- is a positive action, mechanical, friction device. Normal configuration is such that when the power is removed, the brake is set. This can be used as a holding brake. (Note: A Separately Mounted Brake is one which is located on some part of the mechanical drive train other than the motor.)

Breakaway Torque	The torque required to start a machine from standstill. It is always greater than the torque needed to maintain motion.
Breakdown Torque	The breakdown torque of an AC motor is the maximum torque which it will develop with rated voltage applied at the rated frequency.
Bridge Rectifier	A full wave rectifier that conducts current in only one direction of the input current. AC applied to the input results in approximate DC at the output.
Bridge Rectifier (Diode, SCR)	A diode bridge rectifier is a non-controlled full wave rectifier that produced a constant rectified DC voltage. An SCR bridge rectifier is a full wave rectifier with an output that can be controlled by switching on the gate control element.
Bushing (m.v. transformers)	Conductor extending through the tank wall with liquid-tight fittings for connecting electrical internal parts to exterior cables.
“C” Face (Motor Mounting)	This type of motor mounting is used to close couple pumps and similar applications where the mounting holes in the face are threaded to receive bolts from the pump. Normally, the “C” face is used where a pump or similar item is to be overhung on the motor. This type of mounting is a NEMA standard design and available with or without feet.
Cable Tray (wire mgmt.)	An economical system for supporting cables and wires.
Case (motor)	The external housing of the motor
Cellular Steel Floor System (wire mgmt.)	Corrugated sheet metal floor decking which can be used as electrical raceway.
Circuit Breaker	A device designed to open and close a circuit by non-automatic means and to open the circuit automatically on a predetermined overcurrent without damage to itself when properly applied within its rating.
Circuit Breaker Frame	1. The circuit breaker housing that contains the current carrying components, the current sensing components and the tripping and operating mechanism. 2. That portion of an interchangeable trip circuit breaker remaining when the interchangeable trip unit is removed.

Closed Loop	Closed loop refers to a regulator circuit in which the actual value of the controlled variable (e.g. speed) is sensed and a signal proportional to this value (feedback signal) is compared with a signal proportional to the desired value (reference signal). The difference between these signals (error signal) causes the actual value to change in the direction that will reduce the difference in signals to zero.
Cogging	A condition in which a motor does not rotate smoothly but “steps” or “jerks” from one position to another during shaft revolution. Cogging is most pronounced at low motor speeds and can cause objectionable vibrations in the driven machine.
Common Mode Noise (power conditioning)	This is electrical interference that occurs between the hot wire and ground, or the neutral wire and ground.
Common Trim (lighting panels)	One piece of sheet metal which covers two panelboards mounted side by side.
Commutation (Inverter)	The process by which forward current is interrupted or transferred from one switching device to the other. In most circuits where power is supplied from an AC source, turn-on control is adequate and turn-off occurs naturally when the AC cycle causes the polarity across a given device to reverse.
Comparator	A device that compares one signal to another. This is usually the process signal which is compared to the set point or command signal.
Compartment	Space (air-filled) in which to terminate cable.
Conductor	Materials that allow current to flow easily. The “pipe” for electrons.
Constant Horsepower Range	A range of motor operation where motor speed is controlled by field weakening. In this range, motor torque decreases as speed increases. Since horsepower is speed times torque (divided by a constant), the value of horsepower developed by the motor is this range is constant.
Constant Torque Range	A speed range in which the motor is capable of delivering a constant torque, subject to the cooling limitations of the motor.

Constant Voltage Range	(AC Drives) The range of motor operation where the drive's output voltage is held constant as the output frequency is varied. This speed range produces motor performance similar to a DC drive's constant horsepower range.
Constant Volts per Hertz (V/Hz)	This relationship exists in AC drives where the output voltage is varied directly proportional to frequency. This type of operation is required to allow the motor to produce constant rated torque as speed is varied.
Contactor Reversing	A method of reversing motor rotation by the use of two separate contactors, one of which produces rotation in one direction and the other produces rotation in the opposite direction. The contactors are electrically (and mechanically) interlocked so that both cannot be energized at the same time.
Continuous current rating (handle rating)	The maximum direct current or rms current in [circuit breakers] amperes, at a rated frequency which a device or an assembly will carry continuously without exceeding the specified limits of observable temperature rise.
Continuous Duty	(CONT) A motor that can continue to operate within the insulation temperature limits after it has reached normal operating (equilibrium) temperature.
Continuous Load	A load where the maximum current is expected to continue for three hours or more.
Continuous Rating	Defines the constant load which a transformer can carry at rated primary voltage and frequency without exceeding the specified temperature rise.
Converter	The process of changing AC to DC. This is accomplished through the use of a diode rectifier or thyristor rectifier circuit. The term "converter" may also refer to the process of changing AC to DC to AC (e.g. adjustable frequency drive). A "frequency converter", such as that found in an adjustable frequency drive, consists of a *Rectifier*, a *DC Intermediate Circuit*, an *Inverter* and a *Control Unit*
Core Loss (transformers)	The energy lost in the transformer needed to magnetize the core. Expressed in watts of KW (1000 watts). Core loss is constant and independent of transformer load. It is present all the time a transformer is energized. (See also Iron Loss, No-Load Loss.)

Corrosion Resistant	"Corrosion Resistant" means that a device is so constructed, protected, or treated that corrosion will not exceed specified limits under specific test conditions.
CSA	Canadian Standards Association.
Current (electrical service)	Alternating current (AC) or direct current (DC)
Current (represented as an “I”)	The flow of electrons. Current is measured in amperes, (commonly abbreviated as “amps”).
Current Limiting	An electronic method of limiting the maximum current available to the motor. This is adjustable so that the motor’s maximum current can be controlled. It can also be preset as a protective device to protect both the motor and control from extended overloads.
Current-Limiting Circuit Breaker	A circuit breaker that does not use a fusible element and when operating within its current limiting range, limits the let through current within predetermined acceptable values.
Damping	Damping is the reduction in amplitude of an oscillation in the system.
Dead Band	The range of values through which a system input can be changed without causing a corresponding change in system output.
Decibel (dB)	A term used in sound measurement. A change of one dB in sound level is the smallest change the human ear can detect. A busy office might measure from 65-70 dB. dB is a measure of sound intensity.
Delta (Δ)	A standard three-phase connection with the ends of each phase winding connected in series to form a closed loop with each phase 120 degrees from the other. Sometimes referred to as 3-wire.
Delta Voltage System	This system provides three phases and three wires, three “hot” wires. 240 volt and 480 volt are the most commonly used delta systems.
Delta-Wye	A term or symbol indicating the primary connected in delta and the secondary in Wye when pertaining to a three-phase transformer or transformer bank.
Deviation	Difference between an instantaneous value of a controlled variable and the desired value of the controlled variable corresponding to the set point. Also called error.

"D" Flange (Motor Mounting)	This type of motor mounting is used when the motor is to be built as part of the machine. The mounting holes of the flange are not threaded. The bolts protrude through the flange from the motor side. Normally "D" flange motors are supplied without feet since the motor is mounted directly to the driven machine.
di/dt	The rate of change in current versus a rate of change in time. Line reactors and isolation transformers can be used to provide the impedance necessary to reduce the harmful effects that unlimited current sources can have on phase controlled rectifiers (SCRs).
Dielectric	Insulator such as glass, rubber, plastic, etc. that separates two electrical conductors in a transformer or capacitor, for example.
Diode	A device that passes current in one direction, but blocks current in the reversed direction.
Distribution Transformers	Transformers rated 500KVA and below are usually referred to as distribution type. Exceptions include current and potential and other specialty transformers.
Direct current	This can be produced from alternating current or supplied as a direct output from a battery. Direct current always flows in the same direction. In the United States, direct current powers cranes and other industrial equipment. The abbreviation for direct current is "DC".
Door-In-Door (lighting panels)	Trim has an inner door over the branch disconnect area secured with one latch. An outer door covers the gutter area also secured by a single latch. There is another flange around the entire box.
Double or Split Door (lighting panels)	In a lighting contactor panel, one door is used to cover the contactor and the other is used to cove the branch breakers.
Drift	Drift is the deviation from the initial set speed with no load change over a specific time period. Normally the drive must be operated for a specified warm-up time at a specified ambient temperature before drift specifications apply. Drift is normally caused by random changes in operating characteristics of various control components
Driptight	"Driptight" means that a device is so constructed or protected as to excluded falling dirt or drops of liquid under specified test conditions.

Drive Controller	(Also called Variable Speed Drive) An electronic device that can control the speed, torque, horsepower and direction of an AC or DC motor.
Dry Type (transformers)	A dry type transformer is one in which the transformer core and coils are immersed in air or other dry gas.
Dusttight	"Dusttight" means that a device is so constructed so that dust will not enter the enclosure case under specified test conditions.
DutyCycle	The relationship between the operating and rest times or repeatable operation at different loads.
dv/dt	The rate of change in voltage versus a rate of change in time. Specially designed Resistor-Capacitor networks can help protect the SCRs from excessive dv/dt which can result from line voltage spikes, line disturbances and circuit configurations with extreme forward conducting or reverse blocking requirements.
Dwell	The time spent in one state before moving to the next. In motion control applications for example, a dwell time may be programmed to allow time for a tool change or part clamping operation.
Dynamic Braking	*See Braking*
Eddy Current	Currents induced in motor components from the movement of magnetic fields. Eddy currents produce waste heat and are minimized by lamination of the motor poles and armature.
EEMAC	Acronym for Electrical and Electronic Manufacturer's Association of Canada. Similar to NEMA in the U.S.
Efficiency	Ratio of mechanical output to electrical input indicated by a percent. In motors, it is the effectiveness with which a motor converts electrical energy into mechanical energy.
Efficiency (transformers)	The efficiency of a transformer is the energy output expressed as a percentage of the energy input and reflects the losses within the transformer. For loads between 25% and 150% of rating efficiencies between 98% and 99.5% would not be untypical.
Electrical Service	Supply power from the utility.

Electrostatic Shield (transformers)	Copper or other conducting sheet placed between primary and secondary and grounded to provide additional protection against electrical interference.
Empty Mounting Units (motor control centers)	Includes a removable undrilled panel with a hinged door to provide space for customer-installed devices in a Motor Control Center.
Enable	To allow an action or acceptance of data by applying an appropriate signal to the appropriate input.
Encapsulated Winding (transformers)	Transformer having coils either dipped or cast in an epoxy resin.
Enclosure	Enclosure refers to the housing in which the control is mounted. Enclosures are available in designs for various environmental conditions.
Enclosure Temperature (transformers)	Sum of the ambient temperature and the temperature rise of the enclosure allowed by standards.
Encoder	An electromechanical transducer that produces a serial or parallel digital indication of mechanical angle or displacement. Essentially, an encoder provides high resolution feedback data related to shaft position and is used with other circuitry to indicate velocity and direction. The encoder produces discrete electrical pulses during each increment of shaft rotation.
Equipped Space (motor control centers)	This is sometimes requested as space for future units in a Motor Control Center. Fully bussed space is available for future starter units.
Error	Difference between the set point signal and the feedback signal. An error is necessary before a correction can be made in a controlled system.
Excitation Current	The steady state current that keeps the transformer energized after the inrush has dissipated.
Exciting Current	Current which flows in any winding used to excite the transformer when all other windings are open-circuited and is usually expressed in percent of the rated current of a winding in which it is measured.
Eye-Bolt Bushing (m.v. transformers)	Bushing with integral screw clamp for one cable only.

FA (m.v. transformers)	Forced Air. Indicated cooling by virtue of fans to provided forced air-flow. Always used in conjunction with the self-cooled designation as in OA/FA or AA/FA.
FCAN (transformers)	Full capacity above normal nameplate voltage.
FCBN (transformers)	Full capacity below nominal. Abbreviation which, when pertaining to transformers, designated that they are suitable for full-rated KVA at voltages below rated level.
FFA (m.v. transformers)	Future forced air. Indicated provisions have been made for field installation of forced-air cooling. (See also FA.)
Feedback	The element of a control system that provides an actual operation signal for comparison with the set point to establish an error signal used by the regulator circuit.
Filter	A device that passes a signal or a range of signals and eliminates all others.
Floating Ground	A circuit whose electrical common point is not at earth potential or the same ground potential as circuitry it is associated with. A voltage difference can exist between the floating ground and earth ground.
Force	The tendency to change the motion or position of an object with a push or pull. Force is measured in ounces or pounds.
Four-Quadrant Operation	The four combinations of forward and reverse rotation and forward and reverse torque of which a regenerative drive is capable. The four combinations are: 1. Forward rotation/forward torque (motoring) 2. Forward rotation/reverse torque regeneration) 3. Reverse rotation/reverse torque (motoring) 4. Reverse rotation/forward torque regeneration)
Frame Size (Motors)	The physical size of a motor, usually consisting of NEMA defined “D” and “F” dimensions at a minimum. The “D” dimension is the distance in quarter inches from the center of the motor shaft to the bottom of the mounting feet. The “F” dimensions relates to the distance between the centers of the mounting feet holes.
Frame Size (circuit breakers)	A term applied to a group of molded case circuit breakers which are physically interchangeable with each other. Frame size is expressed in amperes and corresponds to the largest ampere rating available in the group.

Frequency	The number of cycles per second for an AC electric system; the number of times per second that the current flow changes direction.
Frequency of Current (electrical service)	This applies only to alternating current (AC). In the United States it is usually 60 hertz. Outside the United States 50 hertz is common.
Front of a Motor	The end opposite the coupling or driving pulley (NEMA). This is sometimes called the opposite pulley end (O.P.E.) or commutator end (C.E.).
Full-Capacity Tap (transformers)	Tap through which the transformer can deliver its rated KVA output without exceeding the specified temperature rise.
FLC (motor control)	This is the electrical current required during normal motor operation to generate its designed horsepower. Full load current is also known as full load amps (FLA). A motor's full load current is used when selecting motor overload protection devices.
Full-Load Torque	The full-load torque of a motor is the torque necessary to produce rated horsepower at full-load speed.
Fully Rated Selectively Coordinated	This is a fully rated system with an additional system (circuit breakers) design characteristic: within the range of selectivity, overcurrent protective device closest to the fault, opens the circuit, while the upstream overcurrent protective device remains closed. This limits unnecessary interruption of service to unaffected portions of the system. A system coordination study may be advisable to assure optimum selectivity.
Fully Rated System (circuit breakers)	In this system, the interrupting rating of all overcurrent protective devices must be greater than or equal to the available fault current at the lineside terminals of each device.
Gate	The control element of an SCR (silicon controlled rectifier) commonly referred to as a thyristor. When a small positive voltage is applied to the gate momentarily, the SCR will conduct current (when the anode is positive with respect to the cathode of the SCR). Current conduction will continue even after the gate signal is removed.
Generators	Large machines which produce electricity. Generators are found in electrical power plants.

GTO	Gate turn-off or gate turn-on power semiconductor device.
General-Purpose Motor	This motor has a continuous Class "B" rating and design, listed and offered in standard ratings with standard operating characteristics and mechanical construction for use under usual service conditions without restriction to a particular application or type of application (NEMA).
Handle Rating (circuit breakers)	See continuous current rating.
Harmonic	A component frequency of a current or voltage that is an integral multiple of the fundamental frequency.
Hertz	A unit of frequency equal to one cycle per second. Abbreviated Hz.
High Power Factor	When the active power component equals or is very near to the total power such as for a purely resistive load, the highest power factor possible would be 1.0, or 100% unity.
Hinged Trim (lighting panels)	Alternative to door-in-door construction. Has piano hinge on one side, door opens by a single latch.
Horsepower	The amount of work done by a machine. Relative to motors, horsepower Indicates the power of the motor. Motor horsepower is a selection criterion for motor control products such as manual and magnetic motor starters.
Hunting	Undesirable fluctuations in motor speed that can occur after a step change in speed reference (either acceleration or deceleration) or load.
Hysteresis Loss	The resistance offered by materials to becoming magnetized results in energy being expended and corresponding loss. Hysteresis loss in a magnetic circuit is the energy expended to magnetize and demagnetize the core.
IEEE	Institute of Electrical and Electronic Engineers.
IGBT	(Insulated Gate Bipolar Transistor) - Type of power device frequently used in inverter sections of drives. The IGBT is noted for its ease in switching on and off and high switching frequencies.

Impedance (%IZ)	Retarding forces of current flow in ac circuits. With respect to transformers, it is the measure of the transformer's resistance and reactance to current flow.
Induction Motor	An alternating current motor in which the primary winding on one member (usually the stator) is connected to the power source. A secondary winding on the other member (usually the rotor) carries the induced current. There is no physical electrical connection to the secondary winding, its current is induced.
Inductive Loads	Any type of load that has a coil of wire as the current-drawing element (i.e. motor winding, ballast, transformer).
Inertia	A measure of a body's resistance to changes in velocity, whether the body is at rest or moving at a constant velocity. The velocity can be either linear or rotational. The movement of Inertia (WK^2) is the product of the weight (W) of an object and the square of the radius of gyration (K^2). The radius of gyration is a measure of how the mass of the object is distributed about the axis of rotation. WK^2 is usually expressed in units of lb-ft^2.
Input devices (motor control)	Control products that start the initial action of a control system. These devices send electrical signals to a second type of product called logic devices.
Inrush (motor)	High initial peak of current occurring during the first few cycles of motor energization.
Instability	The state or property of a system where there is an output but no corresponding input.
Insulator	Materials that do not allow current to flow easily. It is wrapped around individual wires to prevent the current flow to undesirable places.
Isolation (power conditioning)	The magnetic separation of the input and output of a transformer device with a grounded shield in between them.
Insulation System	Balancing of insulation materials to properly insulate a given product.
Integral Horsepower Motor	A motor built in a frame having a continuous rating of 1 HP or more.
Integral Main (lighting panels)	The main disconnect device is inside the panelboard.

Intermittent Duty	(INT) A motor that never reached equilibrium temperature (equilibrium), but is permitted to cool down between operations. For example, a crane, hoist, or machine tool motor is often rated for 15 or 30 duty.
Interrupting Rating	See AIR.
Inverter (AC Drive)	A term commonly used for an AC adjustable frequency drive. An inverter is also a term used to describe a particular section of an AC drive. This section uses the DC voltage from a previous stage (Intermediate DC Circuit) to produce an AC current or voltage having the desired frequency.
Inverter (UPS)	This is the circuit in a UPS that converts DC voltage from the battery into AC voltage for the load.
IOC	(Instantaneous Over-Current) IOC is a fault condition that occurs when an excessive amount of current passes through the drive. This type of fault occurs when the current exceeds the current rating of the drive by 250% to 350%. Unlike an overload condition, IOC will trip the drive instantaneously.
IPM	(Intelligent Power Module) Module which contains IGBT's and "intelligent" switching circuit. The IPM can be used as a self-contained inverter.
IR Compensation	A way to compensate for the voltage drop across resistance of the AC or DC motor circuit and the resultant reduction in speed. This compensation also provides a way to improve the speed regulation characteristics of the motor, especially at low speeds. Drives that use a tachometer-generator for speed feedback generally do not require and IR compensation circuit because the tachometer will inherently compensate for the loss in speed.
Iron Loss	See Core Loss.
Isolation Transformer	A transformer that electrically separates the drive from the AC power line. An isolation transformer provides the following advantages: 1. In DC motor applications, it guards against inadvertent grounding of plant power lines through grounds in the DC motor armature circuit.

	2. Enhances protection of semiconductors from line voltage transients.
	3. Reduces disturbances from other solid state control equipment such as drives without isolation transformers, time clock systems, electronic counters, etc.
Jogging	Jogging is a means of accomplishing momentary motor movement by repetitive closure of a circuit using a single push-button or contact element.
K Factor (power conditioning, transformers)	Refers to specially designed transformers that can withstand harsh harmonic currents, particularly in the neutral conductor.
KVA or Volt-Ampere Output	The KVA or volt-ampere rating designates the output which a transformer can deliver for a specified time at rated secondary voltage and rated frequency without exceeding the specified temperature rise (1KVA=1000-VA).
KVAR (kilovars)	Reactive or non-working power provides the magnetic flux necessary for the operation of the device but is not transformed into any useful work.
KW (kilowatts)	Active or working power is the power which is converted into useful work.
Kinetic Energy	The energy of motion possessed by a body.
Limit Switch (motor control)	This is one type of input device. It is a type of sensor that is designed to detect physical contact with an object.
Linear Acceleration/Deceleration	(LAD) A circuit that controls the rate at which the motor is allowed to accelerate to a set speed or decelerate to zero speed. On most drives, this circuit is adjustable and can be set to accommodate a particular application.
Linearity	A measure of how closely a characteristic follows a straight line function.
Linear Loads	The waveform of the current is the same as the waveform of the voltage.
Liquid-Immersed Transformer (m.v. trans.)	Transformer with core and coils immersed in liquid (as opposed to a dry-type transformer).
Load (Mechanical)	External resistance to movement that must be overcome by a motor , under a given condition, measured in the power required.

Load (electrical)	An electrical path of varying resistance which connects to the electrical system. Loads are any device which uses electricity. For example, appliances or lights.
Load Center	A box for the distribution of electrical current located either inside or outside the house which connects to the service entrance conductors. Often mistakenly called a “circuit breaker box” or “fuse panel”. The proper name is a load center.
Load (transformers)	Expression of power in KVA or volt amperes-supplied by the transformer.
Load Losses (transformers)	See Winding Loss.
Locked-Rotor Current	Steady state current taken from the line with the rotor at standstill (at rated voltage and frequency). This is the current when starting the motor and load.
Locked-Rotor Torque	The minimum torque that a motor will develop at rest for all angular positions of the rotor (with rated voltage applied at rated frequency).
Logic Devices	They receive electrical signals from input devices and make decisions based on preset information. They then send electrical signals to output devices. Examples of logic devices are relays, timers and programmable logic controllers.
Low power factor (I/R)	When the non-working power is a large component of the total power, such as lightly loaded motors, the power factor could be .5 or 50%, which would be a ratio of 1/2 or 50% power factor.
LRC (motor)	Locked Rotor Current. This is the amount of electrical current required to start and accelerate a motor to its rated speed. Locked rotor current may also be called locked rotor amps (LRA) or inrush current. A motor’s LRC is used when selecting motor overload protection devices.
Main Bus Bars	Main conductors of electricity, which are inside the load center, are composed of copper or aluminum strips.
Main Circuit Breaker	Switch which is connected to the main bus bars that can disconnect power to the entire load center.

Maximum Speed	The setting on the drive which determines the highest frequency that the drive will output.
Meggar Test	A test used to measure an insulation system's resistance. This is usually measured in megohms and tested by passing a high voltage at low current through the motor windings and measuring the resistance of the various insulation systems.
Mid-Tap (transformers)	A reduced-capacity tap midway in a winding - usually the secondary.
Minimum Speed	The setting on the drive which determines the lowest frequency that the drive will output.
Motor Load	The energy that a machine requires from a motor in order to operate, measured in torque.
Motor Nameplate	This plate is attached to each motor. It provides motor information and specifications, such as horsepower, full load current, service factor, voltage and frequency, and the type of current. The motor nameplate is a primary source for information necessary to select control products.
Motor Overload	This is a condition which exists when a motor load increases above normal. The motor draws more current in an attempt to produce more energy to meet the increased motor load. The additional current increases the temperature inside the motor. Higher than normal temperatures will cause damage to the motor.
Multispeed Motor	An induction motor that can obtain two, three or four discrete (fixed) speeds by the selection of various stator winding configurations.
NEMA	National Electrical Manufacturers Association. The focus of NEMA is to establish voluntary standards for its members to ensure that the products they manufacture have general areas of uniformity. NEMA produces more than 200 standards publications.
NEC	The National Electrical Code is recommendations of the National Fire Protection Association and is revised every three years. City or state regulations may differ from code regulations and take precedence over NEC rules.
Negative Feedback	A condition where feedback is subtractive to the input reference signal. Negative feedback forms the basis for automatic control systems.

NEMA Class 1 (motor control centers)	Independent units consisting of mechanical groupings of combination motor control units, feeder taps, and electrical devices arranged for convenient assembly. Wiring is complete between components within each unit. Connections between units are not provided.
NEMA Class 2 (motor control centers)	Interconnected units consisting of mechanical groupings of combination motor control units, feeder taps, and electrical devices arranged for convenient assembly. Electrical interlocking and wiring between units is provided. These interconnections are completed as called out by the purchaser.
NEMA Drilling (m.v. transformers)	Prescribed hole pattern in spade terminals, lugs and other connectors. Usually 1-3/4" on center in square pattern for 4-hole, repetitive pattern for six or more.
NEMA Type 1 Enclosure	General Purpose. Primarily protects against accidental contact with enclosed equipment. Suitable for indoor use.
NEMA Type 12 Enclosure	Indoor Dusttight and Driptight. Without knockouts. Protects against liquids that are not corrosive including oil and coolants. Often found in an industrial environment.
NEMA Type 12K Enclosure	Same as Type 12 but with knockouts in top and bottom walls only.
NEMA Type 3 Enclosure	Dusttight, Raintight. Protects against dust and rain. Used outdoors. They are not sleet (ice) proof. Applications include ship docks, subways, and tunnels.
NEMA Type 3R Enclosure	Rainproof, Sleet Resistant. Protects the normal operation of the enclosed equipment from interference due to rain, and resists equipment damage due to sleet. For outdoor use in location affected by rain and/or sleet.
NEMA Type 4 Enclosure	Watertight. Protects against water interfering in the operation of the enclosed equipment. The enclosure may be used outdoors or in dairies or other food preparation environments.
NEMA Type 4X Enclosure	Watertight, Corrosion Resistant. Protection is similar to NEMA Type 4 except Type 4X enclosure is constructed of corrosion resistant material. Used in fertilizer and chemical manufacturing plants, meat packing plants where environmental contaminants would destroy the metal enclosure over time.

NEMA Type 5 Enclosure	Indoor Dusttight. Intended for use indoors to protect enclosed equipment against fibers and flyings, lint, dust, and dirt.
NEMA Type 7 Enclosure	Class 1, Group A, B, C and/or D. Indoor Hazardous Locations. Protects against explosions caused by electrical arcs that occur during normal operation of motor control or switching equipment. The enclosure is constructed to prevent flammable gases or vapors from entering the enclosure. Used in oil refineries and natural gas plants. Do not decide between NEMA Type 7 or NEMA Type 9 for your customers. Let them tell you which enclosure type will meet their requirements.
NEMA Type 9 Enclosure	Similar to NEMA Type 7 except the enclosure protects against environmental (airborne) dust. Used in grain elevators and flour milling plants. Do not decide between NEMA Type 7 or NEMA Type 9 for your customers. Let them tell you which enclosure type will meet their requirements.
NEMA Type A (motor control centers)	User field wiring connects directly to internal device terminals in the unit and is provided only on Class 1 Motor Control Centers.
NEMA Type B (motor control centers)	User field control wiring connects directly to the control unit terminal block(s) in or adjacent to each unit and user field load wiring connects directly to the device adjacent to the vertical wireway.
NEMA Type C (motor control centers)	User field control wiring on all units and load wiring on Size 3 or smaller units connects directly to master terminal blocks mounted at the top and bottom of those vertical sections containing control units. Control wiring on all units and load wiring on Size 3 or smaller units are factory wired to their mater terminal block. User field load wiring for Size 4 or larger units connects directly to the device terminals.
NFPA	National Fire Protection Association. This association has developed a set of minimum standards for electrical installations in home, commercial and industrial environments, called the National Electrical Code (NEC). Although the NEC is nationally accepted in the industry, it standards are subject to interpretation by local authorities. Each town, city, county or state may establish codes to govern the installation of electrical equipment or wiring.

Noise (power conditioning)	Unwanted electrical signals which produce undesirable effects in circuits in which they occur.
No-Load Loss	See Core Loss.
Offset	The steady state deviation of a controlled variable from a fixed setpoint.
Oil Resistant Gaskets	Gaskets (used in an enclosure) that are made of those materials which resist oil or oil fumes.
Oiltight	"Oiltight" means that a device is so constructed or protected as to exclude oils, coolants, and similar liquids under specified test conditions.
One Line Diagram	A simplified wiring diagram with a single line representing all the conductors and symbols representing the elements of the system.
Open Loop	A control system that lacks feedback.
OP Amp	An *Operational Amplifier* is usually a high-gain DC amplifier that is designed to be used with external circuit elements.
Open Machine (Motors)	A machine having ventilating openings which permit passage of external cooling air over and around the windings of the machine. A. *Dripproof Machine* is an open type machine in which ventilating openings are so constructed that successful operation is not interfered with when drops of liquid or solid particles strike or enter the enclosure at any angle from 0 to 15 degrees downward from vertical. B. *Splashproof Machine* is an open type machine in which ventilating openings are so constructed that successful operation is not interfered with when drops of liquid or solid particles strike or enter the enclosure at any angle not greater than 100 degrees downward from the vertical. C. *Semiguarded Machine* is an open machine in which part of the ventilating openings in the machine, normally the top half, are guarded as in the case of a “guarded machine” but the others are left open.

D. *Guarded Machine (NEMA Standard)* is an open machine in which all openings giving direct access to live metal or rotating parts (except smooth rotating surfaces) are limited in size by the structural parts or by the screens, baffles, grilles, expanded metal or other means to prevent accidental contact with hazardous parts. Openings giving direct access to such live or rotating parts shall not permit the passage of a cylindrical rod 0.75 inch in diameter.

E. *Dripproof Guarded Machine* is a dripproof machine whose ventilating openings are guarded in accordance with the definition of a guarded machine.

F. *Open Externally Ventilated Machine* is one which is ventilated by means of a separate motor driven blower mounted on the machine enclosure. This machine is sometimes known as a blower-ventilated or a force-ventilated machine.

G. *Open Pipe Ventilated Machine* is basically an open machine except that openings for admission of ventilating air are so arranged that inlet ducts or pipes can be connected to them. Air may be circulated by means integral with the machine or by means external to the machine (separately or forced ventilated).

H. *Weather-Protected Machine* is an open enclosure divided into two types:

   1. *Type 1* enclosures have ventilating passages constructed to minimize the entrance of rain, snow, airborne particles and prevent passage of a 0.75 inch diameter cylindrical rod.

   2. *Type 2* enclosures provide additional protection through the design of their intake and exhaust ventilating passages. The passages are so arranged that wind and airborne particles blown into the machine can be discharged without entering directly into the electrical parts of the machine. Additional baffling is provided to minimize the possibility of moisture or dirt being carried inside the machine.

Operating/Service Deviation	A means of specifying the speed regulating performance of a drive controller generally in percent of base speed.
Operating Deviation	Defines speed change due to load change and typically assumes: 1. A change from one steady state load value to another (not transient). 2. A 95% maximum load change.
Service Deviation	Defines speed change due to changes in ambient conditions greater than these typical variations:

Condition	**Change**
AC Line Voltage	± 10%
AC Line Frequency	± 3%
Ambient Temperature	15° C

Output Devices	They receive electrical signals from logic devices. Two examples of output devices are contactors and starters.
Overcurrent (circuit breakers)	Any current in excess of the rated current of equipment or the ampacity of a conductor.
Overcurrent Condition	Excessive circuit current which could damage equipment connected to the circuit. Typically a circuit breaker is designed to sense overcurrent conditions. When it does the breaker opens the electrical path protecting the connected equipment from being damaged by excessive current. When this happen the circuit breaker is said to have “tripped”. When the situation that caused an overcurrent has been corrected, power can be restored to the circuit. This is done by moving the circuit breaker handle from its trip position to the “off” position to reset it. Then the handle can be moved to the “on” position.
Overload Capacity	The ability of the drive to withstand currents beyond the systems continuous rating. It is normally specified as a percentage of full load current for a specified time period. Overload capacity is defined by NEMA as 150% of rated full load current for one minute for *Standard Industrial DC Motors*.
Overshoot	The amount that a controlled variable exceeds desired value after a change of input.

Overvoltage	Overvoltage is a fault condition that occurs when the input voltage to the drive exceeds the trip value. Overvoltage is not a parameter that can be adjusted.
Panelboards	A single panel or group of panel units designed for assembly in the form of a single panel; including buses, automatic overcurrent devices, and equipped with or without switches for the control of light, heat, or power circuits; designed to be placed in a cabinet or cutout box placed in or against a wall or partition and accessible only from the front.
Phase (∅, or PH)	One of three streams of current which is produced by a generator. Each phase of current flows from a generator in a separate conductor.
Phases(electrical service)	Single phase or polyphase, which is normally three phases.
Plugging	Plugging refers to a type of motor braking provided by reversing either line voltage polarity or phase sequence so that the motor develops a counter-torque which exerts a retarding force to brake the motor.
Plug-on Connection	Describes how an interior device is connected to a vertical bus.
Poke Thru Fittings (wire mgmt.)	A flexible and inexpensive method of providing power receptacles, computer access, and telecommunications services in an existing facility.
Position Transducer	An electronic device (e.g. encoder or resolver) that measures actual position and converts this measurement into a feedback signal convenient for transmission. This signal may then be used as an input to a programmable logic controller which controls the parameters of the positioning system.
Positive Feedback	Positive feedback is a condition where the feedback is additive to the input signal.
Power	Work done per unit of time. Measured in HP or watts: 1 HP = 33,000 ft-lb/min = 746 watts
Power factor	The ratio of active power to total power. Power factor can be expressed as percentage or as a raw number. For example, .80 or 80%. If active power equals total power, the power factor of the load would be 1 or 2 or 100%. This is the highest power factor possible.

Preset Speed	Preset speed refers to one or more fixed speeds at which the drive will operate.
Primary Taps (transformers)	Taps added in the primary winding
Proof (Used as a suffix)	"Proof" means a device is constructed, protected, or treated so that successful operation of the apparatus is not interfered with when subjected to the specified material or condition. Such as "rainproof."
Pull-In Torque	(Synchronous Motors) The maximum constant torque which a synchronous motor will accelerate into synchronism at rated voltage and frequency.
Pull-Out Torque	(Synchronous Motors) The maximum running torque of a synchronous motor.
Pull-Up Torque	The torque required to accelerate the load from standstill to full speed (where breakdown torque occurs), expressed in percent of running torque. It is the torque required not only to overcome friction, windage and product loading but also to overcome the inertia of the machine. The torque required by a machine may not be constant after the machine has started to turn. This load type is characteristic of fans, centrifugal pumps and certain machine tools.
Pushbuttons (motor control)	Devices which are activated manually by a person.
Pulse Width Modulation (PWM)	A type of AC adjustable frequency drive that accomplishes frequency and voltage control at the output section (inverter) of the drive. The drive's output voltage is always a constant amplitude and by "chopping" (pulse width modulating) the average voltage is controlled.
Radial Feed (m.v. transformers)	Incoming HV cables end at this transformer in a single set of HV bushings.
Rainproof	"Rainproof" means an apparatus is so constructed, protected, or treated as to prevent rain, under specified test conditions, from interfering with successful operation of the apparatus.
Raintight	"Raintight" means that a device is so constructed or protected as to exclude rain under specified test conditions.

Reactance	Any force that opposes changes in current or voltage. The inertia of electrons causes them to oppose sudden changes in current flow or voltage.
Rectifier	A device that transforms alternating current into direct current.
Regeneration	A characteristic of a motor to act as a generator when the CEMF is larger than the drive's applied voltage (DC drives) or when the rotor synchronous frequency is greater than the applied frequency (AC drives).
Regenerative Braking	The technique of slowing or stopping a drive by regeneration. See also *Braking.*
Regenerative Control	A regenerative drive contains the inherent capability and/or power semi-conductors to control the flow of power to and from the motor.
Regulation	The ability of a control system to hold a speed once it has been set. Regulation is given in percentages of either base speed or set speed. Regulation is rated upon two separate sets of conditions: A. *Load Regulation (speed regulating)* is the percentage of speed change with a defined change in load, assuming all other parameters to be constant. Speed regulation values of 2% are possible in drives utilizing armature voltage feedback, while regulation of 0.01% is possible using digital regulator schemes. B. *Line Regulation* is the percentage of speed change with a given line voltage change, assuming all other parameters to be constant.
Relay Section (motor control centers)	Includes a full height, full width removable panel with a 72" hinged door to provide space for customer devices in a Motor Control Center.
Remote Main	Main disconnect device is outside the panelboard.
Resistance (represented as an "R"):	This is the property that prevents electrons from moving. Sometimes it is referred to as a "load". Resistance is measured in ohms.

Resistant (Used as suffix)
"Resistant" means that a device is constructed, protected, or treated so that it will not be damaged when subjected to the specified material or conditions for a specified period of time. Such as "sleet resistant."

Resolution
The smallest distinguishable increment into which a quantity can be divided (e.g. position or shaft speed). It is also the degree to which nearly equal values of a quantity can be discriminated. For encoders, it is the number of unique electrically identified positions occurring in 360 degrees of input shaft rotation.

Reversing
Changing direction of rotation of the motor armature or rotor. A DC motor is reversed by changing the polarity of the field or the armature, but not both. An AC motor is reversed by reversing the connections of one leg on the three phase power line. The reversing function can be performed in one of the following ways:

A. *(DC) Contactor Reversing* is done by changing the phase rotation of an AC motor or the polarity to a DC motor armature with switching contactors. The contactors are operated by momentary push buttons, and/or limit switches to stop the motor and change directions. A zero speed (anti-plugging) circuit is associated with this system to protect the motor and control.

B. *(DC) Field Reversing* is accomplished by changing the DC polarity to the motor shunt field. This type of reversing can be accomplished with DC rated contactors or by means of an electrically controlled solid state field supply.

C. *(DC) Manual Reversing* is the act of reversing the DC polarity to the motor armature by changing the position of a single switch. The switch is usually detented to give a degree of mechanical anti-plugging protection. Limit switches and remote stations cannot be used with this system. Dynamic braking is recommended.

D. *(AC or DC) Static Reversing* is the act of reversing the DC polarity of the DC motor armature or phase rotation of an AC motor with no mechanical switching. This is accomplished electronically with solid state devices. Solid state anti-plugging circuitry is generally a part of the design.

RMS	Root Mean Square
Rotor (motor)	A rotating iron core with wire windings. The rotor is attached to the shaft.
Sensors (motor control)	Devices which are activated when they detect conditions such as the presence of a metal, the pressure of a liquid or gas, or the position of an object.
Series Connected System	A system consisting of a combination of two overcurrent protective devices connected in series. The lineside (main) device must have an interrupting rating equal to or greater than the available fault current at the lineside terminals of the device. The loadside (branch) breaker has a lower interrupting rating. The series rated combinations are based on actual UL testing.
Service Deviation	*See Operating/Service Deviation*
Service Drop Conductors	Electrical wires from the power lines which attach to a house.
Service Entrance	The place where the electric supply from the utility company enters a building.
Service Entrance Conductors	Conductors which are extended from the watt-hour meter to the house.
Service Factor (motor)	This defines a margin of safety that allows for those times when motors might be operated above their rated horsepower. This service factor protects the motor against damage that might be caused by the occasional excessive load. When used on a motor nameplate, a number which indicates how much above the nameplate rating a motor can be loaded without causing serious degradation (i.e., a motor with 1.5 S-F can produce 15% greater torque than one with 1.0 S-F.) When used in applying motors or gearmotors, it is a figure of merit which is used to adjust measured loads in an attempt to compensate for conditions which are difficult to measure or define.
Service Fittings (wire mgmt.)	Sometimes known as "activation units" access the duct system to provide power, computer access, and telecommunications services in an existing facility.
Set Speed	The desired operating speed.

Shaft (motor)	A metal rod mounted in the case using bearing assemblies that allow the shaft to turn (rotate).
Shipping Splits (motor control centers)	Motor Control Centers are shipped in more than one container to ease in handling.
Short Circuit Current Ratings (SCCR)	SCCR are used to select end-use equipment for specific available fault current applications. This maximum current rating applies only to end-use equipment such as switchboards, panelboards and motor control centers. The SCCR covers not only the overcurrent protective device in the end-use equipment, but also the overall construction of the equipment i.e. it is an integrated equipment rating.
Shock Load	The load seen by a clutch, brake or motor in a system which transmits high peak loads. This type of load is present in crushers, separators, grinders, conveyors, winches, and cranes
Silicon Controlled Rectifier	(SCR) A solid state switch, sometimes referred to as a thyristor. The SCR has an anode, cathode and control element called a gate. SCR's are turned on by a voltage pulse applied between the gate and cathode. They are turned off when the current between the cathode and anode reaches zero. The device provides controlled rectification since it can be turned on at will. The SCR can rapidly switch large currents at high voltages. They are small in size and low in weight.
Sinewave (UPS)	This describes the shape of the output wave from the inverter. A sinewave is the same shape as that supplied from the utility.
Single phase voltage system	A single phase voltage system can supply 120 volts or 240 volts. The system uses three wires, two "hot" (carrying current) and one neutral wire
Skew	The arrangement of laminations on a rotor or armature to provide a slight angular pattern of their slots with respect to the shaft axis. This pattern helps to eliminate low speed cogging in an armature and minimize induced vibration in a rotor as well as reduce associated noise.
Skewing	Refers to time delay or offset between any two signals in relation to each other.
Sleet Resistant	"Sleet Resistant" means that an apparatus is so constructed that accumulation and melting of sleet (ice), under specified conditions, will not damage the apparatus.

Sleetproof	"Sleetproof" means that a device is so constructed or protected that the accumulation of sleet (ice), under specified conditions, will not interfere with the successful operation of the apparatus, including the external operating mechanism.
Slewing	Slewing is an incremental motion of the motor shaft or machine table from one position to another at maximum speed without losing position control.
Slip	The difference between rotating magnetic field speed (synchronous speed) and rotor speed of AC induction motors. Usually expressed as a percentage of synchronous speed.
Slip Compensation	Method of increasing the output frequency to maintain motor speed as the load on the motor increases
Spade Bushing (m.v. transformers)	Bushings with flattened surface on which cable lugs can be bolted.
Special Purpose Motor	A motor with special operating characteristics or special mechanical construction or both, designed for a particular application and not falling within the definition of a general purpose or definite purpose motor (NEMA).
Speed Range	The speed minimum and maximum at which a motor must operate under constant or variable torque load conditions. A 50:1 speed range for a motor with top speed of 1800 RPM means the motor must operate as low as 36 RPM and still remain within regulation specifications. Controllers are capable of wider controllable speed ranges than motors because there is no thermal limitation, only electrical. Controllable speed range of a motor is limited by the ability to deliver 100% torque below base speed without additional cooling.
Speed Regulation	The numerical measure in percent, of how accurately the motor speed can be maintained. It is the percentage of change in speed between full load and no load.
Split Bus Panelboard	A panelboard with two or three sets of isolated bus bars mounted in the same interior.
Squarewave (UPS)	This is a poor manifestation of a sinewave. This is found on economy models of UPS. This may not be beneficial to most electronic loads.

Squirrel Cage AC Motor	Most commonly used motor in industry and in the home.
Stability	The ability of a drive to operate a motor at constant speed (under varying load), without “hunting” (alternatively speeding up and slowing down). It is related to both the characteristics of the load being driven and electrical time constants in the drive regulator circuits.
Stator (motor)	A stationary iron core with wire windings. The stator is attached to the case.
Steppedwave (UPS)	This waveform combines the benefits of a sinewave with the cost advantages of a squarewave device. This is acceptable to the majority of electronic loads.
Stiffness	The ability of a device to resist deviation due to load change.
Surge Protection	The process of absorbing and clipping voltage transients on an incoming AC line or control circuit. MOVs (Metal Oxide Varistors) and specially designed R-C networks are usually used to accomplish this.
Synchronous Speed	The speed of an AC induction motor’s rotating magnetic field. It is determined by the frequency applied to the stator and the number of magnetic poles present in each phase of the stator windings. Mathematically, it is expressed as: Sync Speed (RPM) = 120 X Applied Freq. (Hz)/Number of poles per phase.
Tachometer-Generator (Tach)	A small generator normally used as a rotational speed sensing device. Tachometers are typically coupled to the shaft of DC or AC motors requiring close speed regulation. The tach feeds a signal to a controller which then adjusts the output voltage or frequency to the motor.
Tap (transformers)	Connection brought out of a winding at some point between its extremities, usually to permit changing the voltage or current ratio.
Thread Speed	A fixed low speed, usually adjustable, supplied to provide a convenient method for loading and threading machines. May also be called a preset speed.

Three Phase Voltage System	Provides three “hot” wires for the customer’s use. The three phase voltage system has two configurations, wye and delta.
Throat (m.v. transformers)	Extension of the cabinet or enclosure that surrounds bushings or cable connections. Used for joining a transformer to adjacent switchgear, busway, etc. Usually rectangular and fitted with a flange for bolting to the connected gear.
Tight (Used as a suffix)	"Tight" means that an enclosure is so constructed that it will exclude the specified material under specified conditions.
Torque (motor)	A turning force applied to a shaft, tending to cause rotation. Torque is normally measured in ounce-inches or pound-feet and is equal to the force applied, times the radius through which it acts
Torque Constant	(in-lbs) This motor parameter provides a relationship between input current and output torque. For each ampere of current applied to the rotor, a fixed amount of torque will result.
Torque Control	A method of using current limiting circuitry to regulate torque instead of speed.
Totally Enclosed Machine (Motor)	A totally enclosed machine is one so enclosed as to prevent the free exchange of air between the inside and the outside of the case. It is not sufficiently enclosed to be termed air-tight. A. *Totally Enclosed Fan-Cooled* is a totally enclosed machine equipped for exterior cooling by means of a fan or fans integral with the machine but external to the enclosing parts. B. *Explosionproof Machine* is a totally enclosed machine whose enclosure is designed and constructed to withstand an explosion of a specified gas or vapor which may occur within it and to prevent the ignition of the specified gas or vapor surrounding the machine by sparks, flashes, or explosions of the specified gas or vapor which may occur within the machine casing.

C. *Dust-Ignition-Proof Machine* is a totally enclosed machine whose enclosure is designed and constructed in a manner which will exclude ignitable amounts of dust or amounts which might affect performance or rating, and which will not permit arcs, sparks or heat otherwise generated or liberated inside of the enclosure to cause ignition of exterior accumulations or atmospheric suspensions of a specific dust on or in the vicinity of the enclosure.

D. *Waterproof Machine* is a totally enclosed machine so constructed that it will exclude water applied in the form of a stream from a hose, except that leakage may occur around the shaft provided it is prevented from entering the oil reservoir and provision is made for automatically draining the machine. The means for automatic draining may be a check valve or a tapped hole at the lowest part of the frame which will serve for application of a drain pipe.

E. *Totally Enclosed Water-Cooled Machine* is a totally enclosed machine which is cooled by circulating water, the water or water conductors coming in direct contact with the machine parts.

F. *Totally Enclosed Water-Air-Cooled Machine* is a totally enclosed machine which is cooled by circulating air which, in turn, is cooled by circulating water. It is provided with a water-cooled heat exchanger for cooling the interior air and a fan or fans, integral with the rotor shaft or separate, for circulating the internal air.

G. *Totally Enclosed Air-to-Air Cooled Machine* is a totally enclosed machine which is cooled by circulating the internal air through a heat exchanger which, in turn, is cooled by circulating external air. It is provided with an air to air heat exchanger for cooling the internal air and a fan or fans, integral with the rotor or separate, for circulating the internal air and a separate fan for circulating the external air.

H. *Totally Enclosed Fan-Cooled Guarded Machine* is a totally enclosed fan-cooled machine in which all openings giving direct access to the fan are limited in size by the design of the structural parts or by screens, grilles, expanded metal, etc., to prevent accidental contact with the fan. Such openings shall not permit the passage of a cylindrical rod 0.75 inch in diameter, and a probe shall not contact the blades, spokes or other irregular surfaces of the fan.

I. *Totally enclosed Air-Over Machine* is a totally enclosed machine intended for exterior cooling by a ventilating means external to the machine.

Transducer

A device that converts one energy form to another (e.g., mechanical to electrical). Also a device that when actuated by signals from one or more systems or media, can supply related signals to one or more other systems or media.

Transfer Time (UPS)

The time it takes for a UPS to “Cut over” from utility power to battery power.

Transformers

The purpose of a transformer is to change the voltage from one level to another. A transformer is composed of three parts: a coil, the primary winding and the secondary winding. “Windings” consist of coils of wire wrapped around the core (which can be made out of iron or metal). If an electrical current is passed through a wire wrapped around a piece of iron/metal, the iron/metal will become magnetized. A magnetic field is created. This illustrates the electromagnetic principle. In a transformer, the electromagnetic principle works as follows: power is fed into the primary winding. The electrical current being fed into the primary winding is transformed into magnetic energy. The core then carries the magnetic energy to the secondary winding. Working in reverse, the secondary winding transforms the magnetic energy back into electrical energy. It is the turns in the transformer that give specific primary and secondary voltages.

Transformer Regulation

The percentage difference between voltage at the secondary terminals under no-load condition versus voltage under full-load. This value depends on the load power factor and is usually reported at 1.0 PF and 0.8 PF.

Transient

A momentary deviation in an electrical or mechanical system

Transistor	A solid state three-terminal device that allows amplification of signals and can be used for switching and control. The three terminals are called the emitter, base and collector.
Transmission lines	Transmission lines carry, or transmit, electricity to homes and businesses.
Transmission Networks	Method by which power plants deliver generated electricity to their customers. Utility companies transmit electrical power at high voltage levels, sometimes as high as 750,000 volts (750kV) because it is less expensive. Power transmitted at high voltage has lower current, and lower current permits the use of a smaller conductor or wire. Operating voltages used in resident, commercial and industrial settings are between 120 volts and 600 volts.
Transverse Mode Noise (power conditioning)	This is electrical interference that occurs between hot and neutral.
Trench Duct (wire mgmt.)	A flush floor wire management system.
Turbines	Machines which drive generators. Turbines are powered by various sources of energy, such as water, coal or nuclear energy.
Underfloor Duct (wire mgmt.)	A concrete encased single compartment or multi-compartment duct system providing distribution and access to power and telecommunications wiring.
Undervoltage	A fault condition that occurs when the input voltage to the drive is below the trip value. Undervoltage is not a parameter that can be adjusted.
UL	Underwriters Laboratories. This is a non-profit corporation that establishes safety and performance standards for electrical products and lists products that meet these standards. Manufacturers who want UL listing make application to UL to list their products. These products are evaluated by a highly-trained technical staff who uses state of the art equipment to determine whether products comply with UL standards. UL also has a network of inspectors who make periodic and unannounced visits to factories. There they check compliance with UL standards in the production of electrical equipment that bears the UL label.
Utility Companies	Supply electricity using power lines.

Variable Volts/Hertz	When the output volts varies at a different rate than the rate at which the output frequency varies. Variable Volts/Hertz is sometimes desired to decrease motor noise and reduce motor core losses.
Vector	A quantity that has magnitude, direction and sense. This quantity is commonly represented by a directed line segment whose length represents the magnitude and whose orientation in space represents the direction.
Voltage (represented as an "E")	The force or "push" needed to move the electrons. Voltage can also be thought of as the difference of force or potential between two points. Voltage is measured in volts.
Voltage Boost	Increasing the Volts/Hertz ratio of drives at low speeds to compensate for resistance losses in the motor core. This compensation allows the motor to develop rated torque at low speeds.
Voltage Regulation	The voltage drop that will occur in the transformer under full load as a percentage of the open circuit voltage rating of the winding. Varies with load and power-factor of the load-.1% to 10% might be outside limits of normal range.
Voltage Regulation (power conditioning)	This is a measurement of a voltage stabilizers ability to hold its output close to the nominal rating despite a fluctuating input. This is normally expressed as a +/- percentage.
VPI (m.v. transformer)	Vacuum Pressure Impregnation. A manufacturing process whereby the coils of a transformer are impregnated with varnish, resin or other process fluid by use of both a vacuum and pressure cycle.
VVI	A type of AC adjustable frequency drive that controls the voltage and frequency to the motor to produce variable speed operation. A VVI type drive controls the voltage in a section other than the output section where frequency generation takes place. The frequency control is accomplished by an output bridge circuit which switches the variable voltage to the motor at the desired frequency.
Wall Duct (wire mgmt.)	A steel-enclosed wall or ceiling lay-in duct system (raceway). Wall duct is UL listed for enclosure of wiring for medical diagnostic equipment.

Watertight	"Watertight" means that a device is so constructed as to exclude water applied in the form of a hose stream, under specified test conditions.
Watthour Meter	Meter mounted on the outside of a house and attached to service drop conductors. This meter measures the amount of electricity used in the house.
Winding Loss (transformers)	The losses, principally I^2R loss in the winding of the transformer, expressed in watts or KW. Winding losses vary with the square of the load.
Wireway	Sheet metal troughs with hinged or removable covers for housing and protecting electric wires and cable and in which conductors are laid in place after the wireway has been installed.
Withstand Rating (circuit breakers)	This is the level of RMS symmetrical current that a circuit breaker can carry with the contacts in the closed position for a maximum of 30 cycles, typically.
Work	A force moving an object over a distance. Measured in inch-ounces (in-oz) or foot-pounds (ft-lbs). Work = Force X Distance.
Wye Connection	A standard three-wire transformer connection with similar ends of the single-phase coils connected. This common point forms the electrical neutral point and may be grounded.
Wye Voltage System	This provides all three phases of current carried by three “hot” wires and one neutral wire. Sometimes it is called a 3 phase 4 wire system. The wye voltage system is the most commonly used three phase voltage system.
X Axis	The axis of motion that is always horizontal and parallel to the work holding surface.
Y Axis	The axis of motion that is perpendicular to both the X and Z axes.
Z Axis	The axis of motion that is always parallel to the principle spindle of the machine.

FINAL TEST

FINAL TEST

Instructions:

So you are ready to take the final test. Great! Record your answers for the questions below. Square D distributors call 1-800-832-4593. The Automated Testing Service will select 10 questions from the Final Test. You will need a touch tone telephone to record your answers. **If you are a Square D employee, call (847) 925-3700 to complete your testing.** Good luck!

Select the best answer:

1. The margin of safety whereby a motor can be occasionally operated either intentionally or unintentionally above its rated horsepower is called:

1. Motor overload
2. Motor slip
3. Motor time rating
4. Motor service factor

2. The torque vs speed relationship is:

1. When torque increases speed also increases
2. When torque increases speed decreases
3. When torque decreases frequency decreases
4. When torque decreases current increases

3. All Square D AC Drives:

1. Use pulse width modulation
2. Control motor speed by varying the motor current
3. Require feedback devices to adjust speed
4. Use an inverter to change 60 Hz constant frequency AC to DC

4. Dynamic braking is when a resistor is used to dissipate the energy being created when the motor starts to act like a generator.

1. True
2. False

5. Whenever AC drives are used to control a motor it means that the speed of the motor is going to be changed. Generally speaking, less speed means less motor cooling.

1. True
2. False

6. A NEMA Design B motor:

1. Is an excellent choice for applications of high inertia loads
2. Has a very high slip range
3. Is an excellent choice for variable torque applications
4. Has a very high locked rotor torque capability

7. Torque is related to current

1. True
2. False

8. Locked rotor amps (LRA) is:

1. The current flow required by a motor during normal operation to produce its designated horsepower
2. The current dissipated through the dynamic braking resistors.
3. The current applied from the electrical distribution system to the motor.
4. The current required by the motor in order for it to start.

9. The synchronous speed of an AC induction motor is determined by the frequency applied to the motor's rotor.

1. True
2. False

10. Examples of constant torque loads would be: conveyors, hoists, drill presses and positive displacement pumps.

1. True
2. False

11. The effects that reduced speed control has on a constant torque fan or pump are summarized by a set of rules know as the Affinity Laws.

1. True
2. False

12. Which is NOT a benefit of AC drives:

1. Energy savings, particularly on fans and pumps
2. Standard AC motors can be used
3. Reduced wear and tear on machinery
4. Low initial investment

13. The most widely used type of motor is the:

1. Direct current
2. Synchronous
3. Wound rotor induction
4. Squirrel cage induction

14. A soft start device reduces voltage and current at startup to relieve stress on the motor and machinery.

1. True
2. False

15. OMEGAPAK Class 8804 Type PT family of AC drives offers:

1. Reliable, cost-effective speed control for low horsepower, standard three-phase AC induction motors.
2. Reliable, cost-effective speed control for high horsepower, standard three-phase AC induction motors.
3. Reliable control for low horsepower, standard single-phase AC induction motors.
4. Speed control for standard AC induction motors.

16. The ALTIVAR 66 drives were developed as a:

1. Temporary product
2. Domestic product
3. Global product
4. Product for export only

17. The ALTIVAR 16 drive has rated power size ranges from:

1. 1/2 to 3 Hp (200-240V AC) and 1 to 5 Hp (400-460V AC)
2. 1 to 5 Hp (120-240V AC) and 10 to 75 Hp (400-460V AC)
3. 3 to 30 Hp (200-240V AC) and 10 to 500 Hp (400-460V AC)
4. 1/2 to 1 1/3 Hp (120V AC) and 5 to 25 Hp (400-460V AC)

18. The ALTIVAR 16 stopping methods are:

1. Freewheel, ramp to S ramp, brake control
2. Freewheel, ramp to stop, brake control
3. Freewheel, ramp to stop, DC injection control
4. Across-the-line stopping, mechanical braking

19. The ALTIVAR 66 horsepower range goes from:

1. 1 to 10 HP variable torque
2. 3 to 150 HP constant torque
3. 1 to 350 HP constant torque
4. 3 to 350 HP constant torque

20. When the ALTIVAR 66 arrives at the user’s location the drive is set up for:

1. Operation with average performance and no factory made adjustments
2. Operation with optimized performance and no factory made adjustments
3. Operation with optimized performance and some factory made adjustments
4. Operation with average performance and some factory made adjustments

21. Communications can be connected to the ALTIVAR 66 through which of the following methods:

1. B1 extension module
2. B1 or B2 extension module
3. Communication card carrier module
4. B1 or B2 extension module or communication card carrier module

22. The ALTIVAR 18 was designed for the OEM market.

1. True
2. False

23. MCC's are manufactured at the _____.

1. Square D Raleigh plant in North Carolina
2. Square D Columbia plant in South Carolina
3. Square D Seneca plant in South Carolina
4. Square D Oxford plant in Ohio

24. MCC with ALTIVAR 66 drives are available at this time in NEMA:

1. Type 1 and Type 12 enclosures only
2. Type 1, Type 1 Gasketed enclosures, and Type 12 only
3. Type 4, Type 4R and Type 12 enclosures only
4. Type 1 only

25. When taking an order for an open type replacement drive, it is important to know the dimensions of the allotted drive space.

1. True
2. False

26. Square D's method for controlling the temperature inside the MCC cabinet is called:

1. Convection Cooling
2. Cooling Management System
3. Thermal Management System
4. Thermal Guard Management System

27. The cooling system maintains the drive's working temperature by:

1. Circulating air across the heat sink of the drive itself
2. Circulating outside air through the cabinet
3. Circulating air conditioned air through the cabinet
4. Circulating inside air around in the cabinet

28. If a user does not have a Square D name plate and designator on the front door of the cabinet, the replacement drive type would be considered:

1. Enclosed type
2. MCC type
3. Open type

29. If the dimensions of the new drive are larger than the original drive, ____ may be required for additional space.

1. Unit extenders
2. Special enclosure doors
3. Split drives
4. A whole new enclosure

30. Where and what should you have the user look for when working with a MCC?

1. On the back of the front door for the Class and Type number
2. Inside the drive's bucket for the data plate and locate the plant code and the Factory Order Number
3. Inside the drive's bucket on the drive itself for the data plate and locate the plant code and the Factory Order Number
4. On the back of the MCC cabinet for the data plate and locate the plant code and the Factory Order Number

31. When identifying a replacement drive for an existing installation that is not in a Square D enclosure:

1. Ask the customer for motor nameplate data
2. Ask the customer for class/or product number from the nameplate on the drive
3. Ask the customer for the class or product number from the enclosure data plate
4. Call the local Square D Sales Office right away

32. Square D's thermal management system:

1. Eliminates "hot spot" problems
2. Reduces environmental contaminates around the drive
3. Eliminates restrictions on drive placement in the MCC structure
4. All of the above

