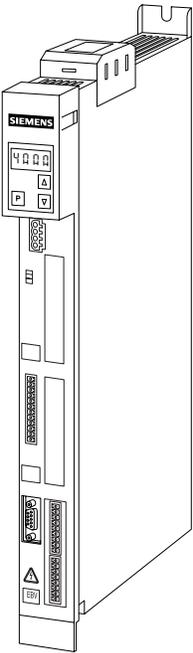


MASTERDRIVE Compact Plus

The Compact Plus is a member of the MASTERDRIVE product line. The Compact Plus offers many of the same features as the larger MASTERDRIVE products in a smaller package. Compact Plus drives are available in ratings from 1 to 25 HP. The Compact Plus is ideally suited for applications requiring high performance where space is at a premium.



X101 and X102 Control Terminals

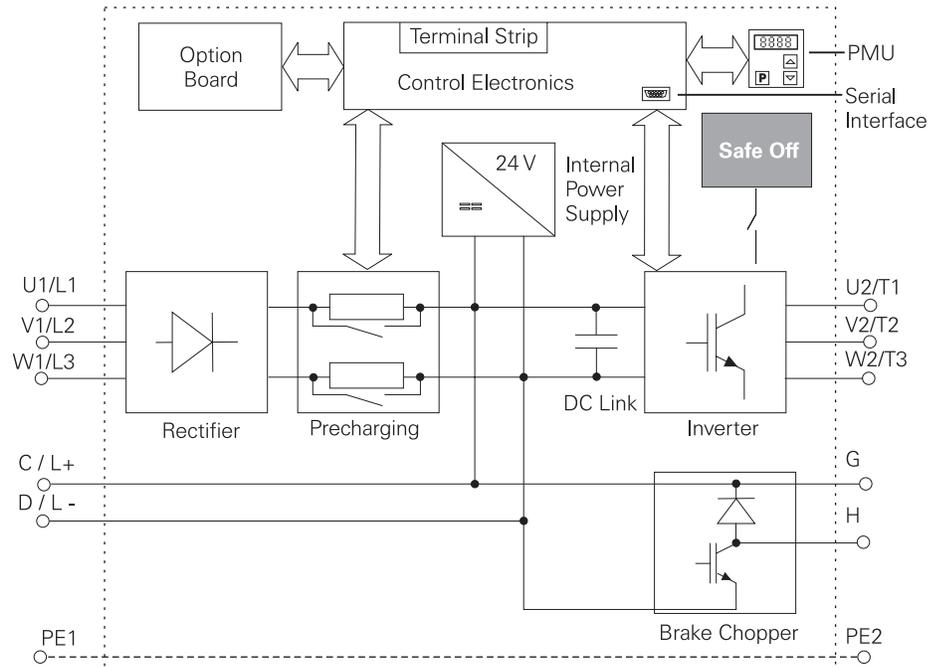
There are four bidirectional digital inputs and outputs. These can be programmed for various functions. Outputs, for example, can be programmed to signal a run or stop condition. Inputs can be programmed as start/stop commands. There are three additional digital inputs, which can be used for high speed inputs with a sampling time of 1 μ s. There are two analog inputs and two analog outputs.

X103 Terminal

An OP1S, PC, or other device can be connected to X103 serial port. An internal link to the USS RS485 interface makes it possible to communicate with other devices which are connected to the serial USS interface.

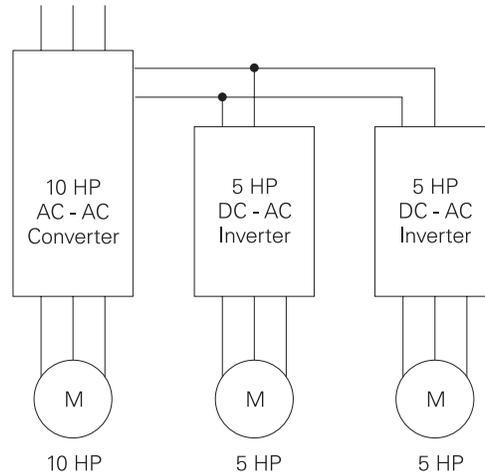
SAFE OFF

SAFE OFF is a function that prevents unintended movement or restarting of a drive after shutdown. This function is available as an option in Compact PLUS drives.



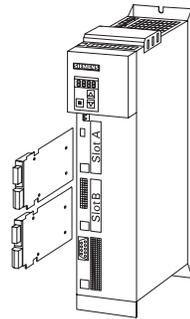
Multi-Motor Systems

Multi-motor drive systems may be implemented with the Compact Plus. Compact Plus AC-AC drive converters can be used to supply power to additional inverters. In the following illustration, for example, a 10 HP converter can also supply two 5 HP inverters.



Option Boards

The capabilities of the Compact Plus can be expanded with the use of option boards. Up to two option boards can be installed in the Compact PLUS unit.



Communication Boards

CBP2	Communication via PROFIBUS-DP
CBC	Communication via CAN Bus
SLB	Communication between Siemens drives via SIMOLINK

Terminal Expansion Boards

EB1	4 Bidirectional Digital Inputs/Outputs
	3 Digital Inputs
	2 Analog Outputs
	3 Analog Inputs
EB2	3 Relay Outputs with Make Contacts
	1 Relay Output with Change-Over Contact
	2 Digital Inputs
	1 Analog Output
	1 Analog Input

Pulse Encoder Evaluation

SBP	Evaluation of an External Encoder (HTL or TTL)
-----	--

Encoder Board

The SBP is used to connect a second pulse encoder to the drive. The SBP can also be used to monitor an external encoder, such as might be connected to the driven machine.

Communication Boards

There are a number of communication boards available for use with the MASTERDRIVE VC. The CBP2 board is used to connect the drive over the open field bus, PROFIBUS-DP. This protocol gives the MASTERDRIVE VC connection to all of Siemens automation products for a totally integrated solution.

SIMOLINK Board

The SLB board is used for peer-to-peer communication with other drives via SIMOLINK. SIMOLINK is a high speed (11 mbaud) fiber optic ring bus that allows various data to be passed from one drive to the next.

Expansion Boards

Expansion boards are used to expand the number of digital and analog inputs and outputs. Depending on the application, EB1 or EB2 can be selected.

Review 5

1. The Siemens MASTERDRIVE can be referred to by a model series number, _____ .
2. A MASTERDRIVE configured so that a common bus supplies power to several AC inverters is referred to as _____ .
3. _____ with a Clean Power Filter is a braking option that returns braking energy to the power source and helps to reduce harmonics.
4. Compact units are available from 3 to _____ HP.
5. Cabinet units are available from _____ to 5,000 HP.
6. To help reduce or eliminate voltage spikes that can occur, a _____ filter should be used with when the distance between a 325 V to 575 V MASTERDRIVE VC and a 1LA5-/1LA6- motor 50 to 100 meters.
7. Compact Plus drives are available from 1 to _____ HP.

Parameters and Function Blocks

The MASTERDRIVE VC features an extensive parameter set that can easily be adapted to almost any drive task, from simple to complex. A wide scope of parameters include:

- Automatic Restart Function
- Restart on the Fly
- Control Modes
- Technology Functions
- Various Arithmetic Operations
- Acceleration/Deceleration Control

In addition the MASTERDRIVE VC supports a wide range of motors. A database of characteristics for specific motors is available, or characteristics for motors not already identified can be input. The MASTERDRIVE VC also supports a large database of faults and alarms. This provides the operator with a clear indication of what is needed to correct the problem.

There are literally hundreds of parameters within the MASTERDRIVE VC. It is beyond the scope of this course to cover these in any detail. However, it is important to understand how parameters and function blocks work together.

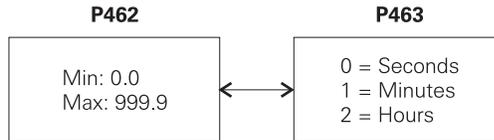
Parameters

A parameter is a variable that is given a constant value for a specific purpose or process. Parameter values are used to provide instructions to the drive. In the Siemens MASTERDRIVE VC each parameter is clearly designated by an assigned number. Parameters are differentiated according to their function:

- Function Parameters (can be read and written)
- Visualization Parameters (can only be read)
- BICO Parameters (can be read and written)

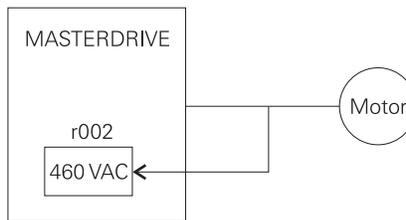
Function Parameters

Acceleration/deceleration times are examples of function parameters. P462 and P463, for example, work together to determine how much acceleration time is needed to accelerate the motor from 0 to 100% speed. P462 can be set between 0.0 to 999.9. P463 can be set for 0, 1, or 2. If P462 were set to 30.00 and P463 were set to 0, then the drive would take 30 seconds to accelerate the motor from 0 to 100% speed.



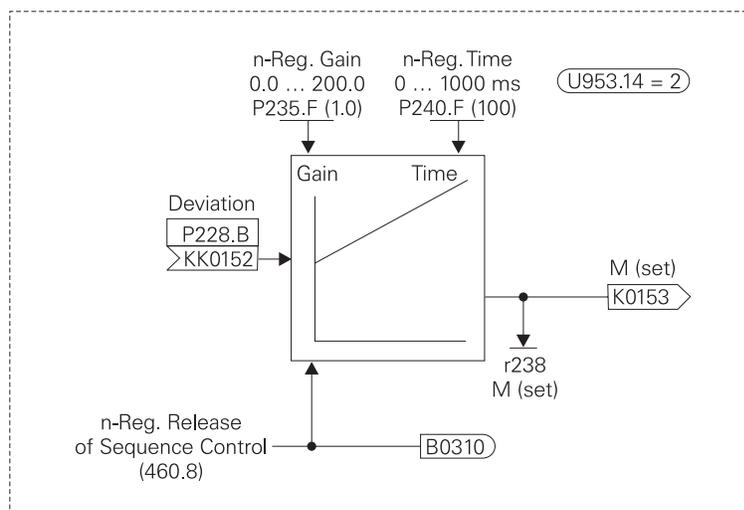
Visualization Parameters

Visualization parameters are used for visualizing internal quantities. These parameters are only displayed and cannot be changed by the operator. Visualization parameters are distinguished by a lower case "r." Parameter r002, for example, displays the value of voltage output to the motor.



Function Blocks

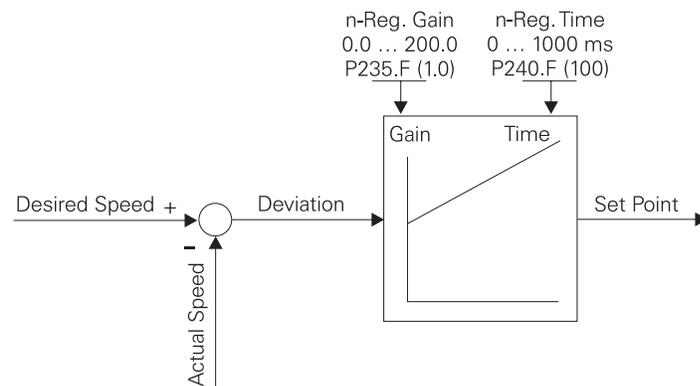
A function block consists of several parameters grouped together to perform a specific task. The following function block represents one example of how a proportional/integral (PI) controller can be used in speed control of a MASTERDRIVE.



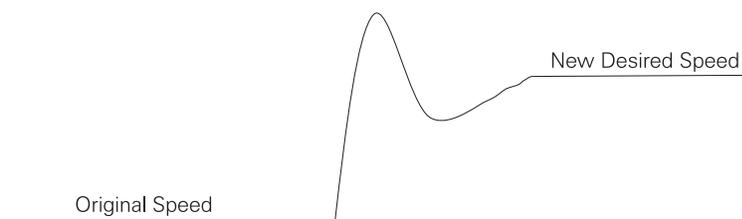
PI-Controller

PI-controllers are commonly used in drive technology. In our example the desired speed and actual speed are input to a summation point. The two signals are opposite in polarity. When the actual speed is equal to the desired speed the deviation, which is input into the PI-controller, is zero (0). Whenever desired speed and actual speed are different there is a deviation.

Changes in load on the motor, for example, can affect motor speed. A sudden increase in load would cause the motor to slow down. This would decrease the feedback from actual speed and the deviation would become more positive. It is also possible that the application may require the motor to slow down or speed up. Until the motor reaches the new desired speed there will be a deviation.

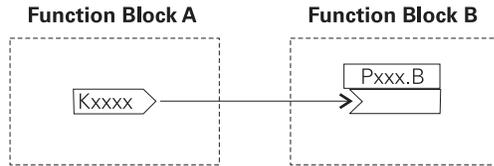


The PI-controller's job is to make speed corrections quickly with a minimal amount of overshoot and oscillation. Parameter P235 (gain) and parameter P240 (time) are used to tune the PI-controller's performance. The end result should be a fast response time with about a 43% initial overshoot. The motor should then settle in to the new desired speed.



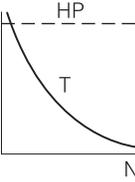
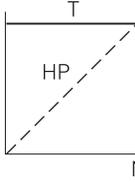
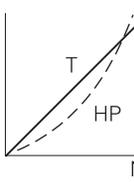
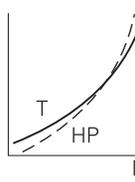
BICO Parameters

BICO is the term used to describe the method of connecting function blocks together. This is performed with **BI**nectors and **CO**nnectors. A connection between two function blocks consists of a connector or binector and a BICO parameter. With BICO parameters you can determine the sources of the input signals of a function block. This allows the user to “softwire” function blocks to meet specific application requirements.



Applications

When applying an AC drive and motor to an application it is necessary to know the horsepower, torque, and speed characteristics of the load. The following chart shows typical characteristics of various loads.

$T \approx \frac{1}{N}$	$T = \text{Constant}$	$T \approx N$	$T \approx N^2$
HP = Constant	HP \approx N	HP \approx N ²	HP \approx N ³
			
Winders Facing lathes Rotary cutting machines	Hoisting gear Belt conveyors Process machines involving forming Rolling mills Planers	Calenders with viscous friction Eddy-current brakes	Pumps Fans Centrifuges

Loads generally fall into one of three categories:

Constant Torque

The load is essentially the same throughout the speed range. Hoisting gear and belt conveyors are examples.

Variable Torque

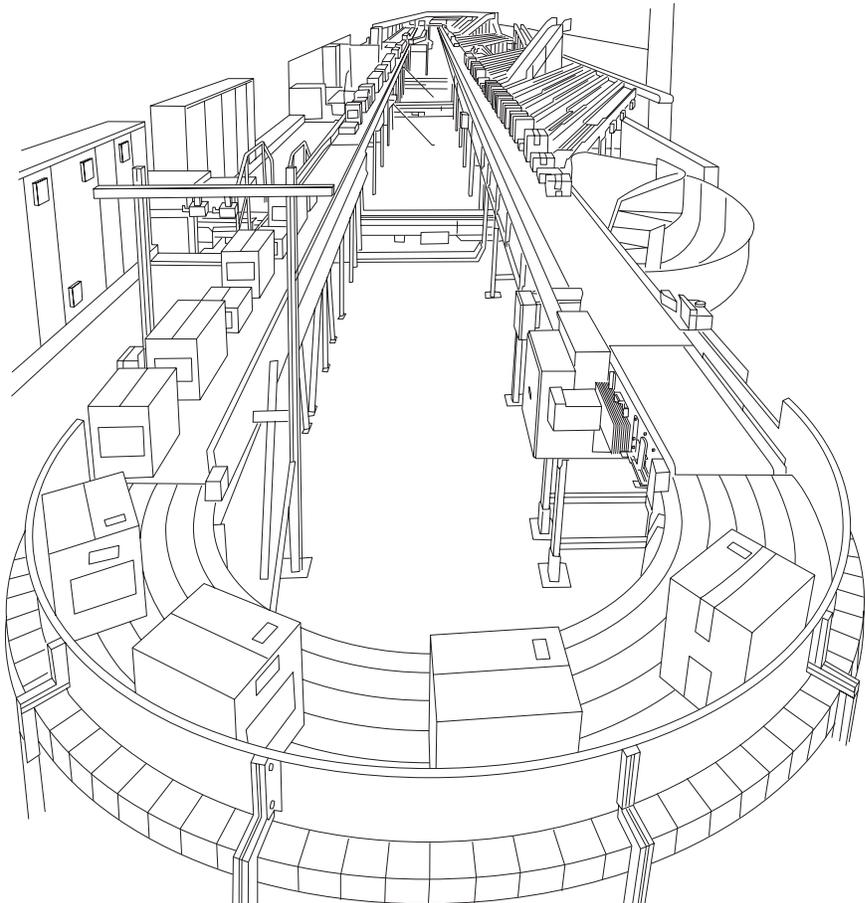
The load increases as speed increases. Pumps and fans are examples.

Constant Horsepower

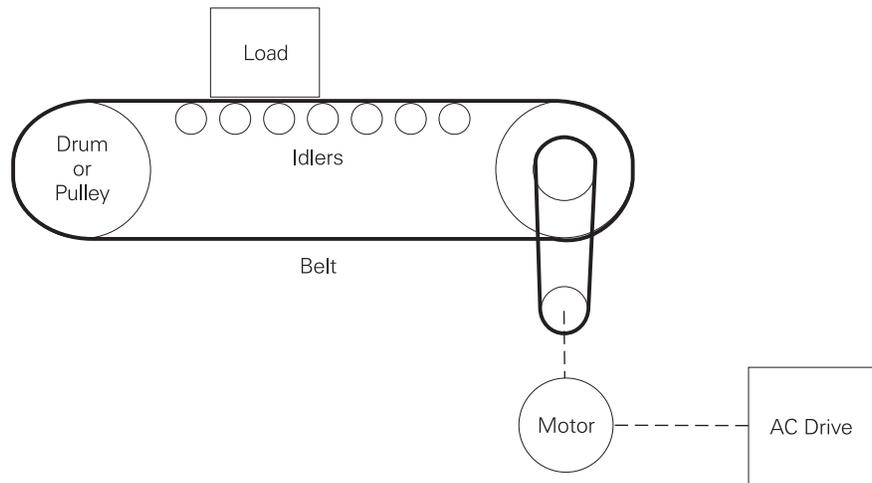
The load decreases as speed increases. Winders and rotary cutting machines are examples.

Constant Torque Applications

A constant torque load implies that the torque required to keep the load running is the same throughout the speed range. It must be remembered that constant torque refers to the motor's ability to maintain constant flux (Φ). Torque produced will vary with the required load. Peak torques in excess of 100% can occur at any speed, including zero speed. One example of a constant torque load is a conveyor similar to the one shown below. Conveyors can be found in all sorts of applications and environments, and can take many styles and shapes.



Conveyors are made up of belts to support the load, various pulleys to support the belt, maintain tension, and change belt direction, and idlers to support the belt and load.



Motor Speed

The speed and horsepower of an application must be known when selecting a motor and drive. Given the velocity in feet per minute (FPM) of the conveyor belt, the diameter in inches of the driven pulley, and the gear ratio (G) between the motor and driven pulley, the speed of the motor can be determined. The following formula is used to calculate conveyor speed.

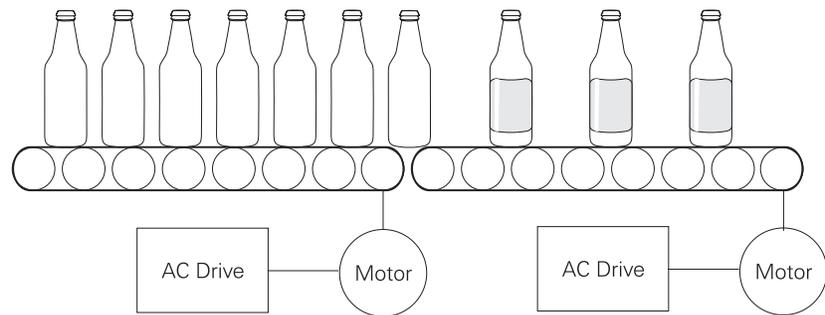
$$\text{Motor RPM} = \frac{\text{Conveyor Velocity (FPM)} \times G}{\pi \times \left(\frac{\text{Diameter in Inches}}{12} \right)}$$

If, for example, the maximum desired speed of a conveyor is 750 FPM, the driven pulley is 18" in diameter, and the gear ratio between the motor and driven pulley is 4:1, the maximum speed of the motor is 638.3 RPM. It would be difficult to find a motor that would operate at exactly this speed. An AC drive can be used with an eight-pole motor (900 RPM). This would allow the conveyor to be operated at any speed between zero and the desired maximum speed of 750 FPM.

$$\text{Motor RPM} = \frac{750 \times 4}{3.14 \times \left(\frac{18}{12} \right)}$$

$$\text{Motor RPM} = 638 \text{ RPM}$$

Another advantage to using AC drives on a conveyor is the ability to run different sections of the conveyor at different speeds. A bottle machine, for example, may have bottles bunched close together for filling and then spread out for labeling. Two motors and two drives would be required. One motor would run the filling section at a given speed and a second motor would run the labeling section slightly faster spreading the bottles out.



Horsepower

Calculating motor horsepower is complicated with many variables, which is beyond the scope of this course. Someone with knowledge of, and experience with conveyor operation would be required to accurately calculate the required horsepower. The horsepower required to drive a conveyor is the effective tension (T_e) times the velocity (V) of the belt in feet per minute, divided by 33,000.

$$HP = \frac{T_e \times V}{33,000}$$

Effective tension (T_e) is determined by several forces:

- Gravitational weight of the load
- Length and weight of belt
- Friction of material on the conveyor
- Friction of all drive components and accessories
 - pulley inertia
 - belt/chain weight
 - motor inertia
 - friction of plows
 - friction of idlers
- Acceleration force when new material is added to conveyor

If the effective tension of a conveyor were calculated to be 2000 pounds and the maximum speed is 750 FPM, then the required horsepower is 45.5.

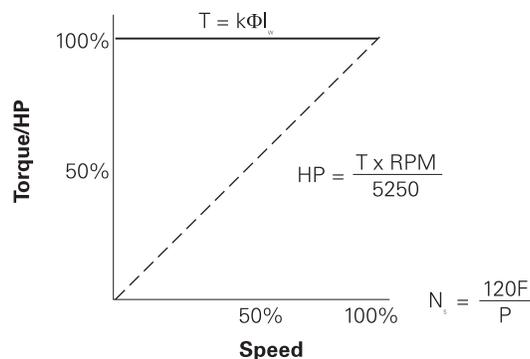
$$HP = \frac{2000 \times 750}{33,000}$$

$$HP = 45.5$$

Starting torque of a conveyor can be 1.5 to 2 times full load torque. A motor capable of driving a fully loaded conveyor may not be able to start and accelerate the conveyor up to speed. AC drives can typically supply 1.5 times full load torque for starting. An engineer may need to choose a larger motor and drive in order to start and accelerate the conveyor.

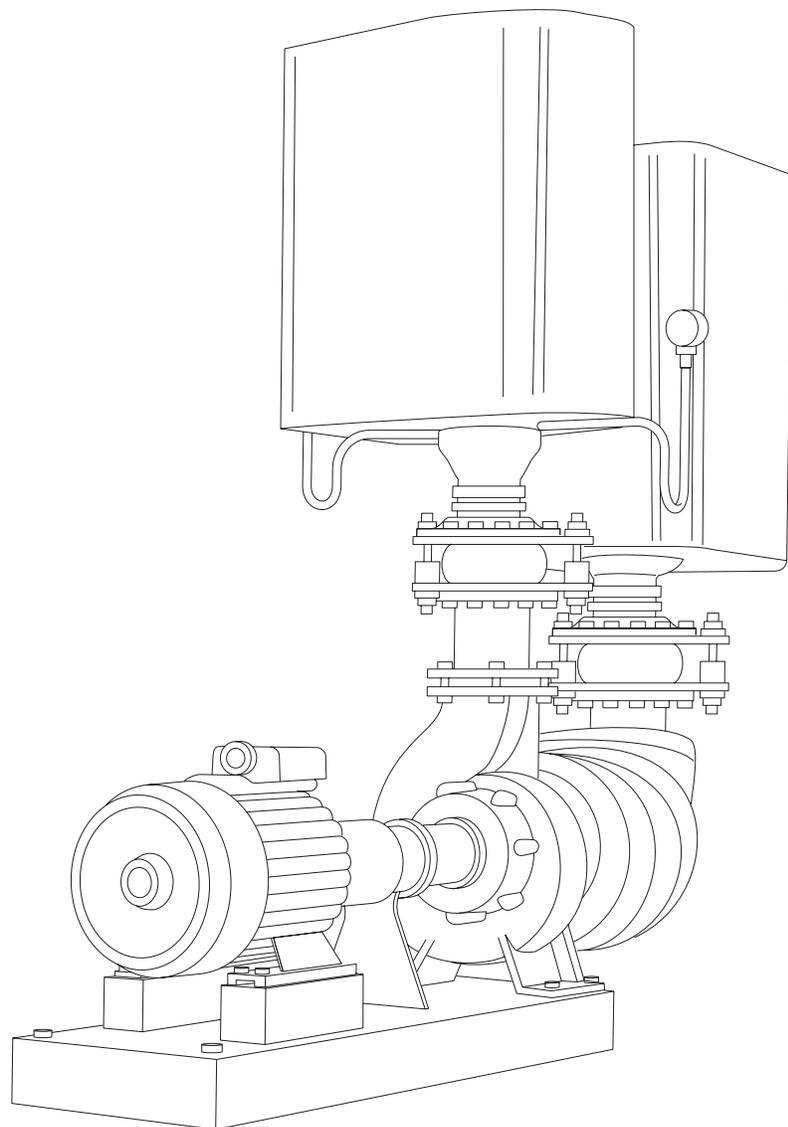
Torque, HP, and Speed

The speed on a conveyor is increased by increasing the AC drive frequency (F) to the motor. Torque (T) is affected by flux (Φ) and working current (Iw). The drive will maintain constant flux by keeping the voltage and frequency ratio constant. To do this the drive increases voltage and frequency in proportion. During acceleration working current will increase, however, causing a corresponding increase in torque. Once at its new speed the working current and torque will be the same as its old speed. The conveyor cannot be operated above the rated frequency of the motor (60 Hz) without losing available torque. Since torque is proportional to (volts/Hz)² any increase in speed will cause available torque to decrease by the square. As a result, the motor will be unable to supply rated torque. Horsepower (HP) is affected by torque and speed. There will be a corresponding increase in horsepower as speed (RPM) increases.



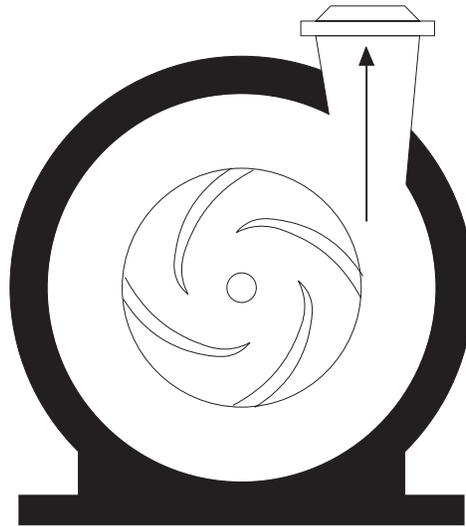
Variable Torque Applications

A variable torque load implies that torque and horsepower increase with an increase in speed. Overloads, as a rule of thumb, are not possible at lower speeds. Peak torques are typically limited to rated torque. Fans and pumps are examples of variable torque. A pump used on a chilled water system is shown below.



Variable Torque Pumps

There are several types of pumps. The most common pump is the end-suction centrifugal pump illustrated below. There are variations of the centrifugal pump. Turbine and propeller pumps are examples. This section deals with variable torque loads. The faster a centrifugal pump turns, the more fluid it pumps and the more torque it requires. It should be noted that not all pumps are variable torque. Reciprocating, positive displacement pumps are constant torque.



Horsepower

Calculating horsepower for a pump application is an involved process that requires someone with a thorough knowledge of the application and pumps. The following information is for illustration only. There are three related horsepower calculations involved in pump applications: liquid, mechanical and electrical.

Hydraulic Head

Hydraulic head is the difference in hydraulic pressure between two points, which actually includes elevation, pressure and velocity. An increase in pump speed would cause increases in pressure and velocity which increases the hydraulic head.

Liquid Horsepower

Liquid horsepower is the hydraulic power transferred to the pumped liquid. The following formula can be used to calculate liquid energy.

Liquid Energy in ft-lb = Total Head x (Gallons x Weight)

Water weighs 8.34 pounds per gallon. If 50 gallons of water per minute were required to be moved through 100 feet of head the energy required would be 41,700 ft-lb/minute.

$$100 \text{ feet} \times (50 \text{ gallons} \times 8.34) = 41,700 \text{ ft-lb/minute}$$

If the pumps speed were increased so that 100 gallons of water were being pumped through 100 feet of head the energy would be 83,400 ft-lb/minute. Twice the energy would be required. The hydraulic head would, in actuality, also increase.

$$100 \text{ feet} \times (100 \text{ gallons} \times 8.34) = 83,400 \text{ ft-lb/minute}$$

The common method of expression is horsepower. One horsepower is equal to 33,000 ft-lb/minute.

Therefore, 41,700 ft-lb/minute is 1.26 HP and 83,400 ft-lb/minute is 2.53 HP.

$$\frac{41,700}{33,000} = 1.26 \text{ HP} \quad \frac{83,400}{33,000} = 2.53 \text{ HP}$$

Mechanical Horsepower

Mechanical horsepower is the horsepower input to the pump and is equal to the liquid horsepower divided by the pump's efficiency. If the liquid horsepower is 2.53 and the pump is 75% efficient the brake horsepower is 3.4 HP.

$$\frac{1.26}{.75} = 1.7 \text{ HP} \quad \frac{2.53}{.75} = 3.4 \text{ HP}$$

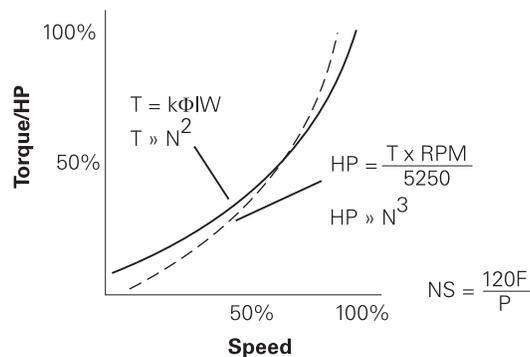
Electrical Horsepower

Electrical horsepower is the horsepower required to run the motor driving the pump and is equal to the mechanical horsepower divided by the motor's efficiency. If the motor is 90% efficient the electrical horsepower is 3.78 HP. It can be seen that with an increase of pump speed there is a corresponding increase in electrical horsepower.

$$\frac{1.7}{.90} = 1.9 \text{ HP} \quad \frac{3.4}{.90} = 3.8 \text{ HP}$$

Torque, HP, and Speed

The speed on a pump is increased by increasing the AC drive frequency (F) to the motor. Torque (T) is affected by flux (Φ) and working current (IW). The drive will maintain appropriate flux by adjusting the voltage and frequency ratio dependent on speed. During acceleration, working current will increase causing a corresponding increase in torque. In this application, torque increases in proportion to the speed squared. This is due to the increase in hydraulic head as the pump works harder to pump more fluid. Horsepower increases in proportion to the speed cubed due to an increase of torque and speed. The pump cannot be operated above the rated frequency of the motor (60 Hz) because the drive will no longer be able to provide constant flux. As a result, the motor will be unable to supply rated torque. The load's torque requirements increase while the motor's ability to supply torque decreases.



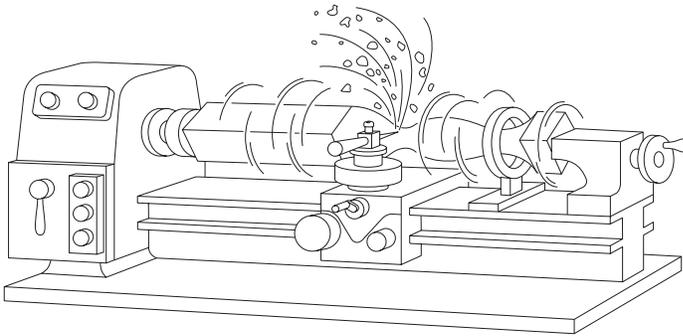
Fans

This same principle applies to fan applications. The horsepower of a fan is determined by dividing the product of air flow (in cubic feet per minute) and pressure by the product of the constant 6356 and fan efficiency. Increasing the speed of the fan increases air flow and pressure, requiring the motor to work harder (IW increases). Torque and horsepower increase.

$$HP = \frac{\text{Flow} \times \text{Pressure}}{6356 \times \text{Fan Efficiency}}$$

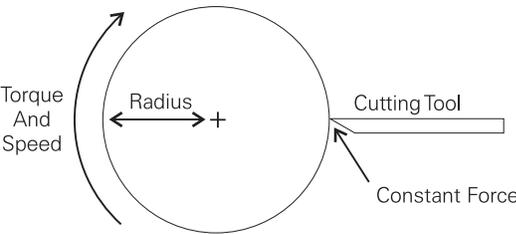
Constant Horsepower Applications

Constant horsepower applications require a constant force as radius changes. A lathe, for example, starts out with a certain diameter object. As the object is cut and shaped the diameter is reduced. The cutting force must remain constant. Another example of a constant horsepower application is a winder where radius increases as material is added to a roll and decreases as material is removed.



Relationship of Speed, Torque, and Horsepower

Applications, such as lathes, that are driven in a continuous circular motion are sometimes referred to as spindle drives. Horsepower will remain constant in a spindle drive application. The surface speed in feet per minute (FPM) is equal to 2π times the radius (in feet) of the material times the speed in RPM. Surface speed will remain constant as the material is shaped and the radius reduced. Torque is equal to force times radius. Horsepower is equal to torque times speed.

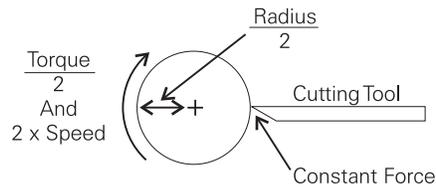


$$\text{Surface Speed (FPM)} = 2\pi \times \text{Radius} \times \text{Speed (RPM)}$$

$$\text{Torque} = \text{Force} \times \text{Radius}$$

$$\text{HP} = \text{Torque} \times \text{Speed}$$

The drive increases the speed (RPM) of the material as the radius is reduced. If the cutting tool has cut away half of the radius, for example, the RPM must double to maintain a constant surface speed (FPM). Reducing the radius by half will cause a corresponding reduction in torque. A doubling of speed (RPM) and a reduction of torque by half causes horsepower to remain constant.

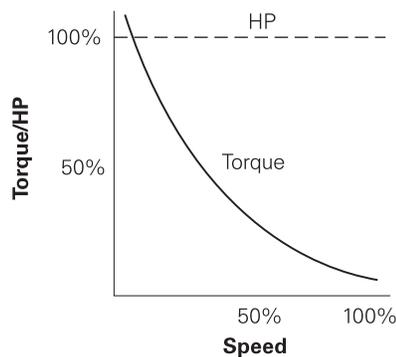


$$\text{Surface Speed (FPM)} = 2\pi \times \frac{\text{Radius}}{2} \times 2 \times \text{Speed (RPM)}$$

$$\text{Torque} = \text{Force} \times \frac{\text{Radius}}{2}$$

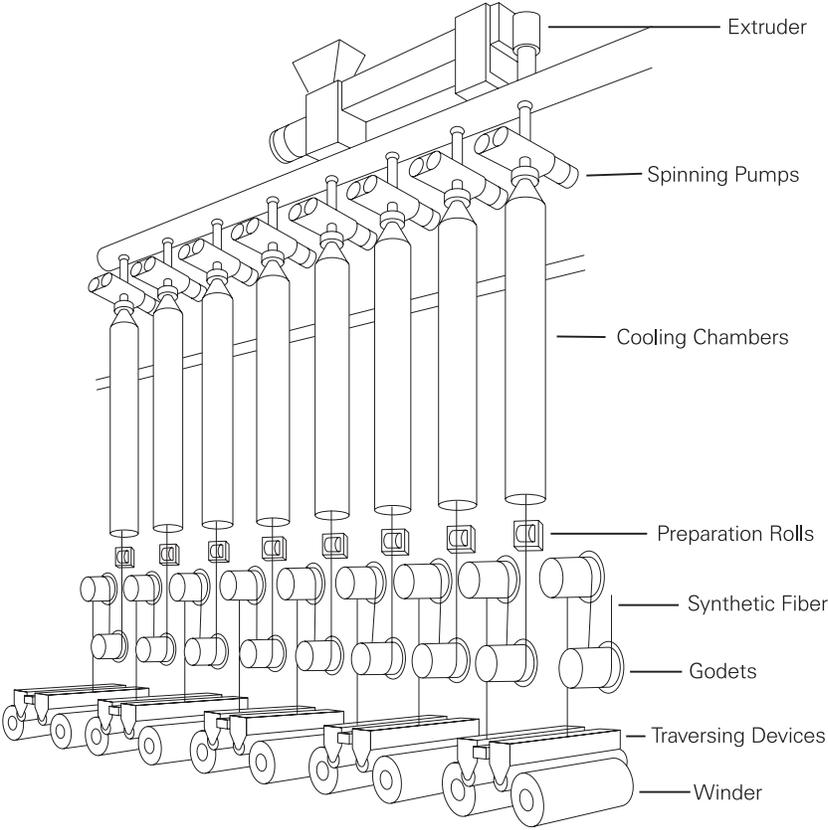
$$\text{HP} = \frac{\text{Torque} \times \text{Speed}}{2}$$

A smaller radius requires less torque to turn. Because torque decreases with a smaller radius, motors operating a constant horsepower application can be run above base speed. A 60 Hz motor, for example, could be run at 90 Hz when the radius is at minimum. RPM must increase to keep surface speed constant. An increase of speed (RPM) and a decrease in torque means horsepower will remain constant.



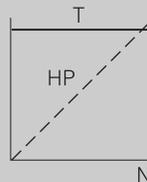
Multimotor Applications

Many applications require more than one motor. In some instances, one drive can supply two or more motors. When this happens, the current rating of the motors added together cannot be greater than the current rating of the drive. Other applications require multiple motors and drives. A spinning machine for producing synthetic fibers, illustrated below, is one example of a multimotor, multidrive application. Various motors run the extruder, spinning pumps, preparation rolls, godets, traversing devices and winders. One drive may supply all the spinning pump motors or all the godet motors or individual motor control for each pump or godet may be used.

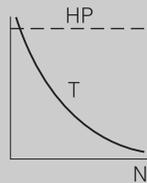


Review 6

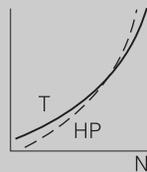
1. Parameters that can be read only are referred to as _____ parameters.
2. A function block consists of several _____ grouped together to perform a specific task.
3. _____ is the term used to describe the method of connecting function blocks together.
4. An application, such as a conveyor, where the torque remains essentially the same throughout the speed range is referred to as _____ torque.
5. Operating a motor above base frequency causes the motor's ability to produce torque to _____ .
 - a. increase
 - b. decrease
6. Fans and pumps are examples of _____ torque applications.
7. Identify the category of the following speed, torque, and horsepower graphs.



a. _____



b. _____



c. _____

Review Answers

Review 1

1) force; 2) 15; 3) torque; 4) 80; 5) inertia; 6) Speed;
7) revolutions per minute

Review 2

1) 5; 2) 1.15; 3) 49.6; 4) 120; 5) 1800, 1500; 6) Slip

Review 3

1) 7.67; 2) increase, increase; 3) b; 4) horsepower; 5)
SIMOVERT; 6) 650; 7) c; 8) d

Review 4

1) P; 2) 650; 3) b; 4) d; 5) II; 6) 100; 7); 3 to 5

Review 5

1) 6SE70; 2) DC - AC; 3) Active Front End; 4) 50; 5) 50; 6) dv/dt ;
7) 25

Review 6

1) visualization; 2) parameters; 3) BICO; 4) constant; 5) b;
6) variable; 7) constant torque, constant horsepower, variable
torque

Final Exam

The final exam is intended to be a learning tool. The book may be used during the exam. After completing the test, mail the tear-out answer sheet in for grading. A grade of 70% or better is passing. Upon successful completion of the test a certificate will be issued.

1. _____ is a twisting or turning force that causes an object to rotate.
 - a. Torque
 - b. Friction
 - c. Inertia
 - d. Acceleration

2. If 50 pounds of force were applied to a lever 3 feet long, the torque would be _____ lb-ft.
 - a. 16.7
 - b. 53
 - c. 47
 - d. 150

3. The rate of doing work is called _____ .
 - a. inertia
 - b. speed
 - c. power
 - d. energy

4. A motor with a rating of 60 KW would have an equivalent rating of _____ HP.
 - a. 45
 - b. 80
 - c. 65
 - d. 120

5. Magnetic lines of flux (Φ) in an AC motor are proportional to _____ .
 - a. voltage divided by frequency
 - b. frequency divided by voltage
 - c. rotor speed divided by synchronous speed
 - d. synchronous speed divided by rotor speed

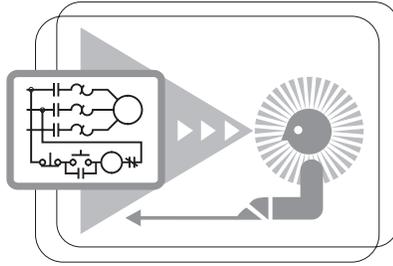
14. The section of an AC drive that controls output voltage and frequency to an AC motor is the _____ .
- a. converter
 - b. DC link
 - c. inverter
 - d. L1 choke
15. Frame size C, 480 volt, MICROMASTER 420 drives are available with power ratings from _____ to _____ horsepower.
- a. 1/2 to 2
 - b. 7.5 to 15
 - c. 3 to 50
 - d. 60 to 500
16. To get four-quadrant operation with a Siemens MICROMASTER an optional _____ must be used.
- a. DC injection brake
 - b. converter bridge
 - c. 4-digit LED display
 - d. braking resistor
17. _____, in conjunction with a Clean Power Filter, provides regenerative control and reduces harmonics.
- a. Active Front End
 - b. Rectifier Regenerative Front End
 - c. 6-Pulse Converter
 - d. 12-Pulse Converter
18. _____ is the term used with the Siemens MASTERDRIVE VC to describe the method of connecting function blocks together.
- a. AFE
 - b. Binector
 - c. BICO
 - d. SBP
19. A centrifugal pump is a _____ application.
- a. constant torque
 - b. constant flux
 - c. constant HP
 - d. variable torque
20. If a conveyor has an effective tension (TE) of 1000 pounds, and a maximum speed of 100 FPM, the required horsepower is _____ HP.
- a. 3
 - b. 25
 - c. 10
 - d. 45

Notes

Notes

Notes

quickSTEP Online Courses



quickSTEP online courses are available at <http://www.sea.siemens.com/step>.

The quickSTEP training site is divided into three sections: Courses, Downloads, and a Glossary. Online courses include reviews, a final exam, the ability to print a certificate of completion, and the opportunity to register in the Sales & Distributor training database to maintain a record of your accomplishments.

From this site the complete text of all STEP 2000 courses can be downloaded in PDF format. These files contain the most recent changes and updates to the STEP 2000 courses.

A unique feature of the quickSTEP site is our pictorial glossary. The pictorial glossary can be accessed from anywhere within a quickSTEP course. This enables the student to look up an unfamiliar word without leaving the current work area.

