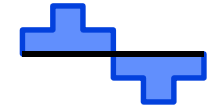


# Applying Adjustable Frequency Drives

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## What Does Applying a Drive Mean?

- Applying a drive is the process of determining the requirements of the driven equipment or process, selecting drive equipment and configuring the drive system to reliably fulfill the requirements.

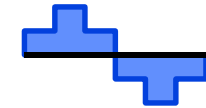


# Applying Adjustable Frequency Drives

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## Load Torque vs. Speed Requirements

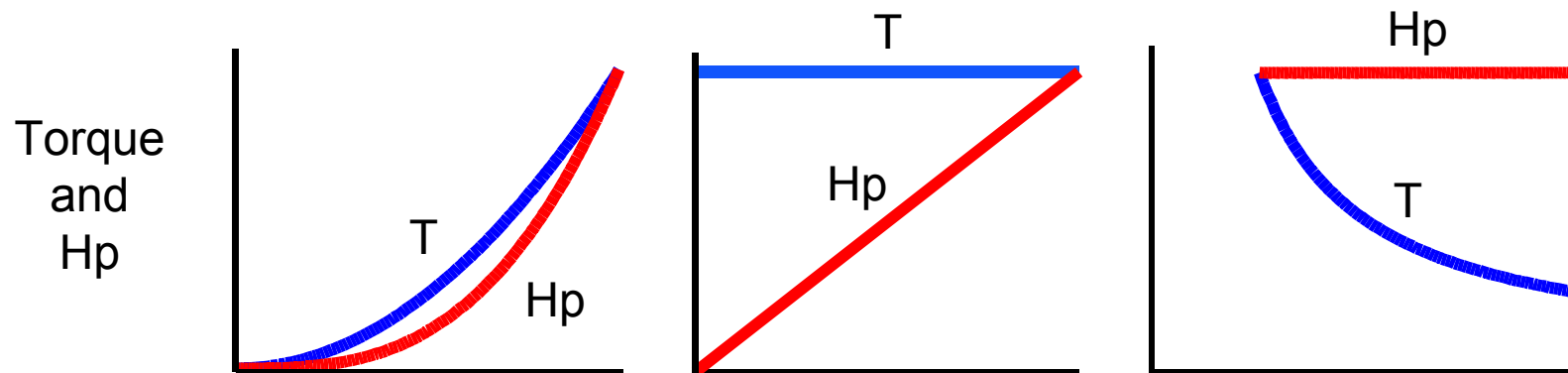
- The primary task of in applying an adjustable speed drive is to define the load torque vs. speed requirements and select a drive controller and motor that can fulfill those requirements.

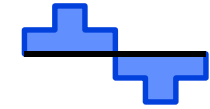


# Applying Adjustable Frequency Drives

## Load Torque vs. Speed Requirements

- What is the basic torque vs. speed category?
  - Variable Torque, Constant Torque or Constant Horsepower

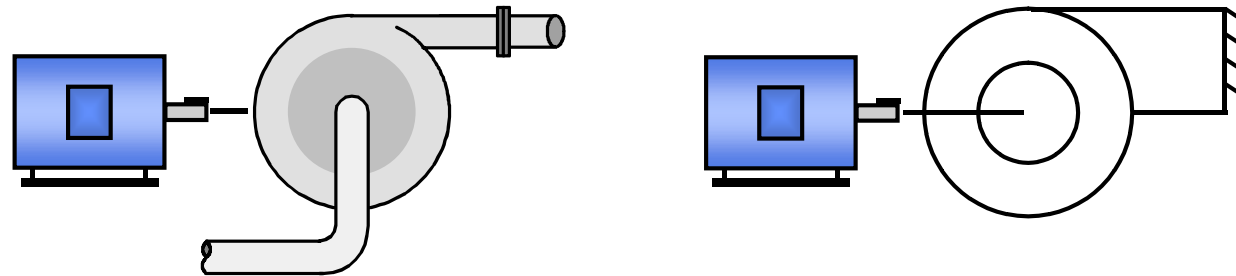


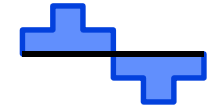


# Applying Adjustable Frequency Drives

## Variable Torque Applications

- Centrifugal pumps and fans are variable torque applications.
  - Positive displacement pumps, positive displacement blowers and compressors are constant torque applications not variable torque.

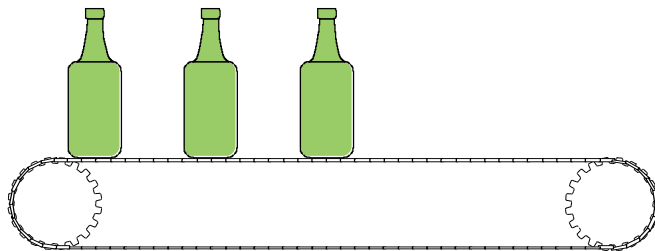


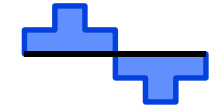


# Applying Adjustable Frequency Drives

## Constant Torque Applications

- Examples of constant torque applications:
  - Conveyors
  - Feeders or screw conveyors
  - Web or filament process rolls
  - Extruders
  - Positive displacement pumps
  - Positive displacement blowers and compressors

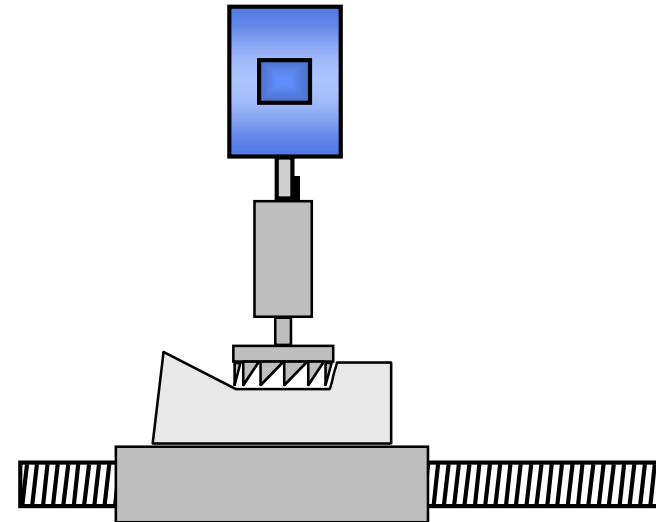
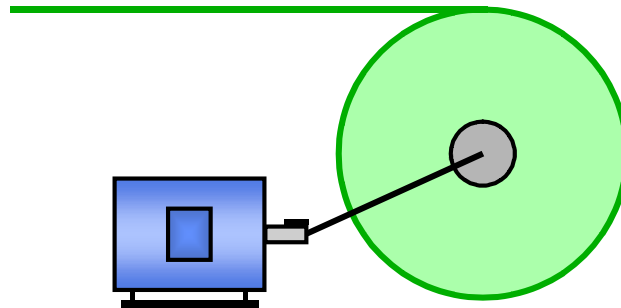


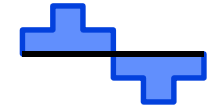


# Applying Adjustable Frequency Drives

## Constant Horsepower Applications

- Center driven winders and most machine tools are constant horsepower applications.



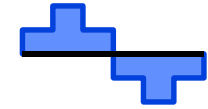


# Applying Adjustable Frequency Drives

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## Total Torque Requirements

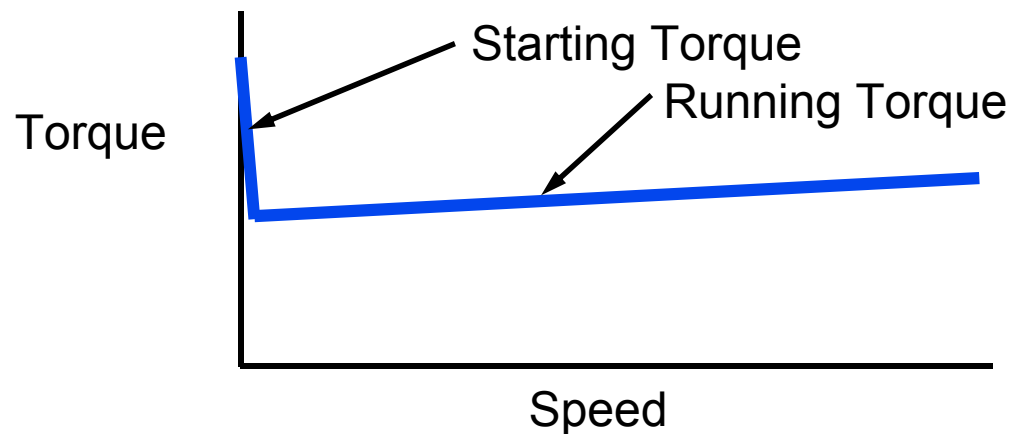
- The total torque requirement of a load may include the following components:
  - Normal running torque - the continuous operating torque categorized in the previous explanation of variable torque, constant torque and constant horsepower loads
  - Additional torque that may be required for brief periods of time
    - Starting Torque
    - Accelerating Torque
    - Intermittent Overload Torque



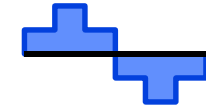
# Applying Adjustable Frequency Drives

## Starting Torque

- Starting torque is the torque required to overcome the static friction of the load and get it moving.
  - Many constant torque applications and some variable torque applications have high starting torque requirements.
  - The starting torque requirement is determined only by the friction of the load at zero speed. Unlike accelerating torque, described in the following slides, starting torque is not influenced by inertia and acceleration rate.







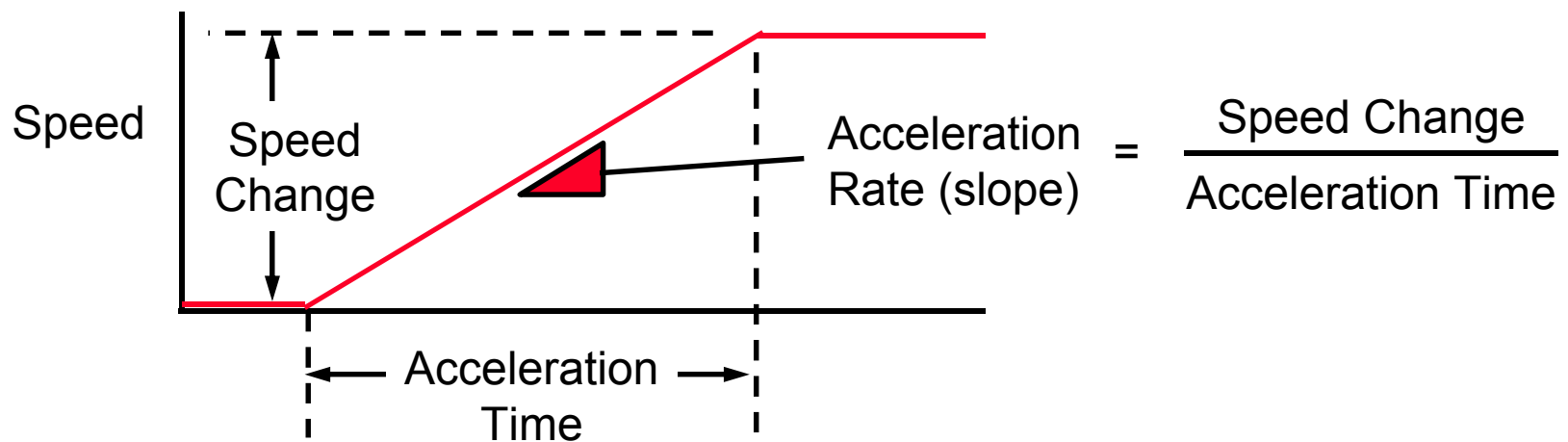
# Applying Adjustable Frequency Drives

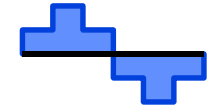
## Acceleration Requirements

### ■ Acceleration Time and Torque

$$\text{Accelerating Torque (lb.-ft.)} = \frac{\text{Acceleration Rate (RPM/sec.)} \times \text{Inertia (WK}^2, \text{lb.-ft.}^2)}{308}$$

- Drives usually follow a linear ramp during acceleration.
- With a linear ramp, the acceleration rate is constant and so the accelerating torque is also constant.



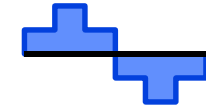


# Applying Adjustable Frequency Drives

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## Acceleration Requirements

- Accelerating torque requirements are often not a significant factor.
  - In many applications, the inertia is not very large and/or the acceleration time is not an important factor in the process.
  - Although some fans and pumps have a large inertia, there are usually no constraints on the acceleration time.



# Applying Adjustable Frequency Drives

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## Deceleration Requirements

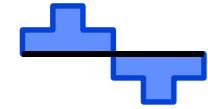
### ■ Deceleration Time and Braking Torque

- Torque required for deceleration

$$\text{Decelerating Torque (lb.-ft.)} = \frac{\text{Deceleration Rate (RPM/sec.)} \times \text{Inertia (WK}^2, \text{ lb.-ft.}^2\text{)}}{308}$$

- Since the normal running torque helps to decelerate the load,

$$\text{Required Braking Torque} = \text{Required Decelerating Torque} - \text{Load Torque}$$

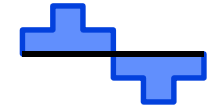


# Applying Adjustable Frequency Drives

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## Intermittent Overload Torque and Time

- In some applications, there is an intermittent, short-time requirement for torque that is greater than the normal operating torque.
  - An intermittent overload torque requirement is torque due a load change rather than torque required to start or accelerate the load.
  - Some constant torque applications have intermittent overload requirements, but variable torque applications don't.

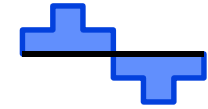


# Applying Adjustable Frequency Drives

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## Sizing the drive for short-time torque requirements

- Determine the sum of the normal operating torque plus the short-time requirement for starting torque, accelerating torque and intermittent overload torque.
- Determine the time required for various levels of torque.
- Select a drive which has an overload rating that is sufficient to handle the short-time requirement and a continuous rating sufficient to handle the continuous requirement.

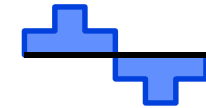


# Applying Adjustable Frequency Drives

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## Speed Range

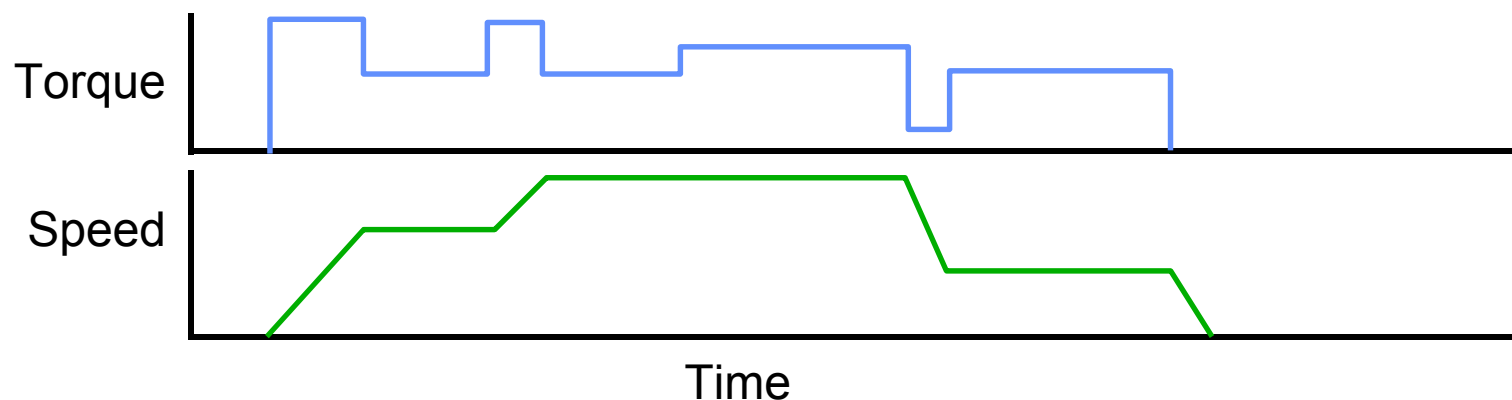
- For variable torque and constant torque applications, determine the maximum and minimum speeds at which continuous operation is required.
- For constant horsepower applications, determine the maximum and minimum speed for constant horsepower operation and define any requirement for constant torque operation below the constant horsepower range.

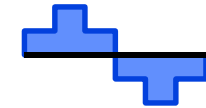


# Applying Adjustable Frequency Drives

## Cyclic Loads

- Some applications require operation at specific speeds and loads for specified periods of time.
  - It may be more economical to select a drive based on the duty cycle rather than select a drive that can operate continuously at the worst-case operating point.
  - The drive duty cycle would usually be defined by drawing a profile of speed and torque vs. operating time.
  - Duty cycle analysis is considered to be an advanced application topic.



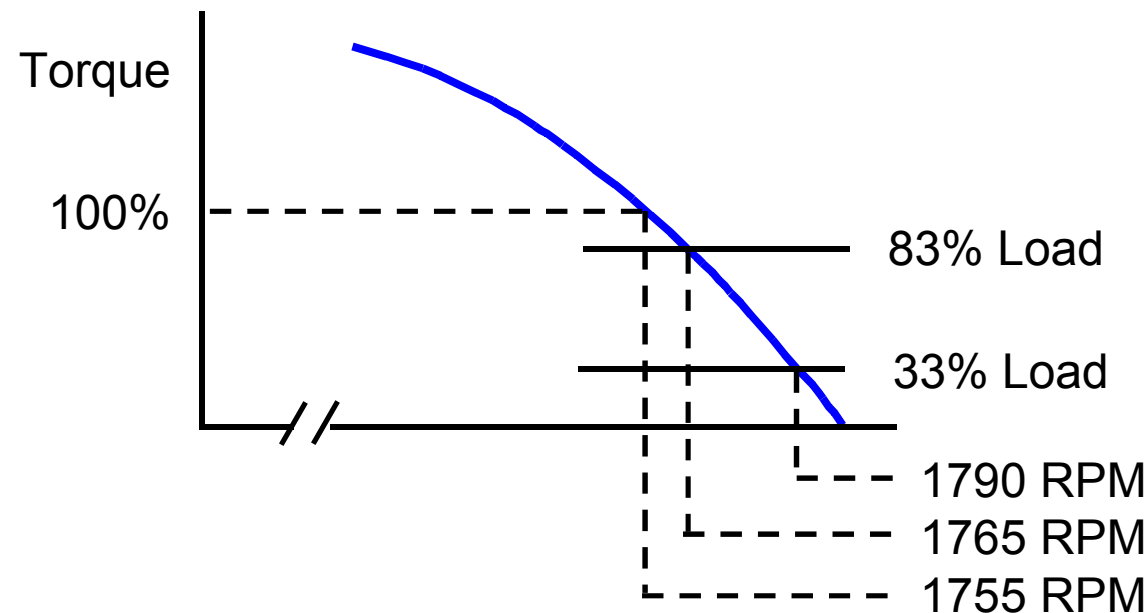


# Applying Adjustable Frequency Drives

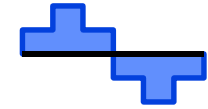
## Static Performance Requirements

### ■ Speed Regulation

- Speed Regulation is generally defined as the percentage speed change that results from a given load change
- In this example, the speed decreased by 25 RPM or about 1.4% when the load increased from about 33% torque to about 83% torque







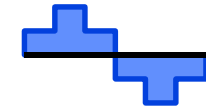
# Applying Adjustable Frequency Drives

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## Static Performance Requirements

### ■ Speed Regulation

- The speed regulating capability of any constant speed motor or adjustable speed drive is defined as the maximum speed change as a percentage of base speed that results from increasing the load from 5% of rated load (essentially no load) to full load while holding constant all other variables that might cause a speed change.
- The speed regulating capability of the motor in the example is:  
$$1800-1755/1755 \times 100 = 2.5\%$$

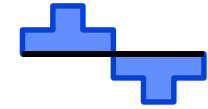


# Applying Adjustable Frequency Drives

## Static Performance Requirements

### ■ Service Deviation

- Speed change due to factors other than load change
- Total speed change due to the maximum variation within the normal limits of service conditions.
  - ≡ Speed change due to all changes within the limits of  $\pm 10\%$  line voltage, 48 to 63 Hz line frequency, 0 to 40°C ambient temperature, etc.
- The term Speed Regulation is sometimes applied to all causes of speed change.
  - ≡ Then the specified speed regulation may include two numbers such as 1/3%.
  - ≡ The first number (1%) is the Operating Deviation, the percentage speed change due to a load change.
  - ≡ The second number (3%) is the Service Deviation, the percentage speed change due to other factors.

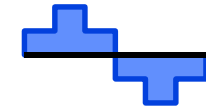


# Applying Adjustable Frequency Drives

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## Dynamic Performance Requirements

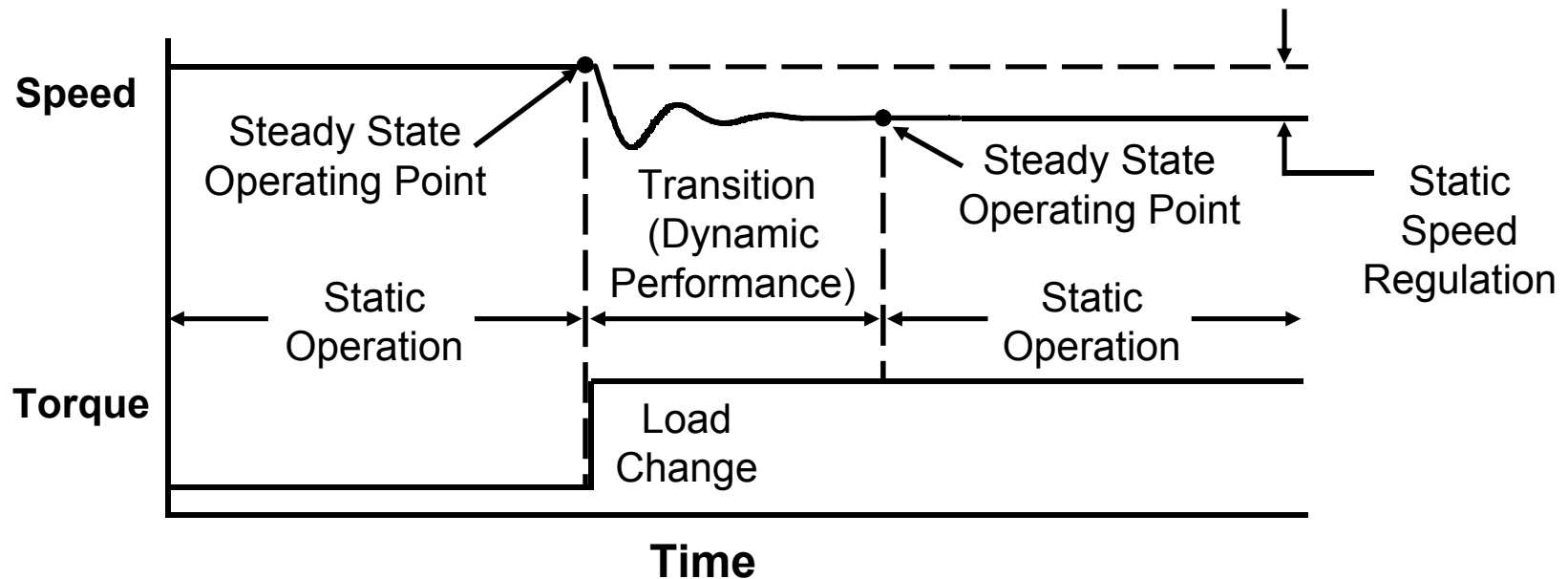
- Speed regulation and service deviation as defined above are static performance parameters.
  - Static Performance measures the difference between two operating points without considering the performance during the transition from one operating point to the other.
  - At each point, operation is measured only after the system has been operating at that point for some length of time.
  - Sufficient time is allowed so that there will be no further change in operation related to the transition from one point to another.
- Dynamic Performance describes the operation during the transition from one operating point to another.

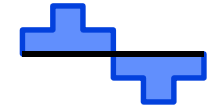


# Applying Adjustable Frequency Drives

## Dynamic Performance Requirements

- A drive system's dynamic performance capability is the system's capability to respond quickly to a change of load or speed command.
  - The figure shows static and dynamic speed regulating performance.
    - ≡ Static operating conditions are shown before and after a load change with a transition period of dynamic performance immediately after the change.



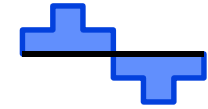


# Applying Adjustable Frequency Drives

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## Dynamic Performance Requirements

- In most applications, the only dynamic performance requirement is that the drive must reliably withstand transition conditions.
- Evaluating more demanding dynamic performance requirements is considered to be an advanced application topic.

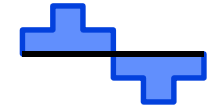


# Applying Adjustable Frequency Drives

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## Position and Torque Regulation

- Most drive applications require only speed regulation.
- Position regulation and torque regulation is considered to be advanced application topics.



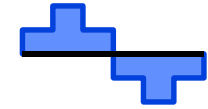
# Applying Adjustable Frequency Drives

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## Other Functional Requirements

### ■ Process Control Functions

- Drives can perform a number of functions that might be considered to be process control functions rather than drive performance functions.



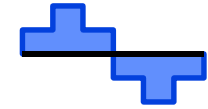
# Applying Adjustable Frequency Drives

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## Interface Requirements

- Operator Interface
  - Most installations must include provisions for run/stop, speed setting and other manual control by an operator.
- Supervisory Control Interface
  - Many installations require the drive to receive run/stop, speed setting and other command signals from supervisory control equipment.
- Annunciation and Instrumentation Interface
  - Installations often require signals to indicate the drive's operating status.
- Interface requirements will be considered in more detail in other sections of this course.





# Applying Adjustable Frequency Drives

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## Installation Compatibility

### ■ Power Source

- The voltage, capacity and other characteristics of the power source must be coordinated with the drive system.

### ■ Environment

- The temperature and other characteristics of the environment must be coordinated with the drive system

- Installation compatibility issues will be considered in more detail in other sections of this course.