

INTRODUCTION TO RATIOCONTROL



Modern industrial processes require operating speeds that maximize production, profit and quality. Today, these speeds can be achieved through mechanical power, fluid power or electrical power. In this section of our Power Transmission 101 course, we will focus on electrical speed drive products and *Ratiotrol* – Boston Gear's trade name for several types of adjustable speed drives.

DEVELOPMENT OF DC TECHNOLOGY

Historically, AC to DC conversion progressed from electromechanical devices, such as the motor-generator set, to vacuum tube controllers and variable transformer/rectifier systems. With the development of the silicon controlled rectifier (SCR) in the early 1960s, a new generation of controllers was developed which, in simple terms:

- Permitted the use of a low voltage "trigger" circuit to control the rectification of AC power, and
- Adjusted the voltage level of the DC output.

Armature voltage feedback and current (load) monitoring circuits provided the means to correct speed changes resulting from load and achieve the best possible relationship between speed signal and actual motor speed.

Later advances in SCR design and associated circuitry led to their use in controlling larger horsepower motors. Optional features, such as adjustable torque, dynamic braking, operator's control stations, master override, multiple set speeds and follower circuits for a variety of signals became commonplace in industrial adjustable speed applications.

With the above background in mind, let's learn more about AC and DC motors.

AC AND DC MOTORS

ALTERNATING CURRENT (AC) MOTORS

All of the electric power in North America is 60-cycle alternating current (AC), meaning that the line voltage and current go through 60 complete cycles per second. The number of cycles per second is referred to as the "line frequency," an electrical characteristic more commonly called Hertz, abbreviated as Hz. In America, we use 60 Hz AC power; most of the rest of the world uses 50 Hz AC power.

The **induction motor** is the most common AC motor used today. This type of motor converts cyclical reversals of electrical energy to rotational mechanical energy. The line frequency and the number of magnetic poles in the stator windings determine the base speed of the motor. If one set of windings (i.e., one pair of poles) is used in the stator, the magnetic field rotates 360-degrees during the AC cycle. (See *Figure 8.1*)

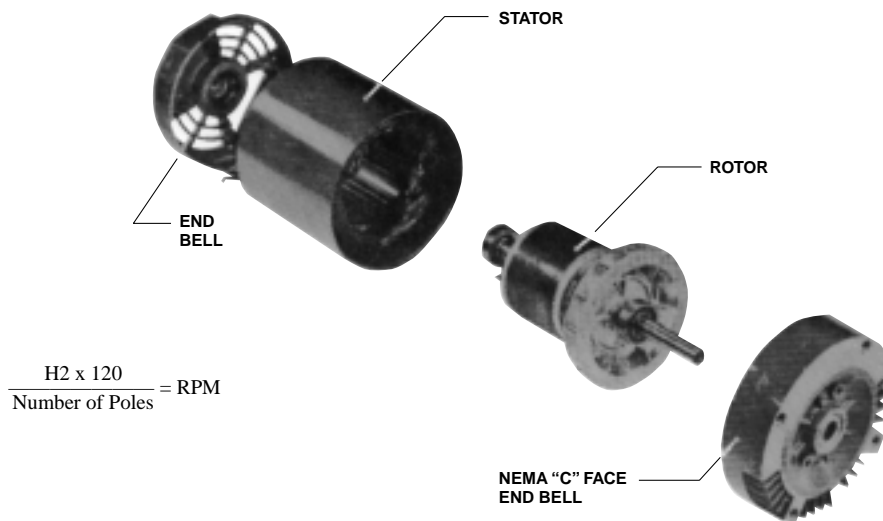


Figure 8.1, Exploded View, AC C-Face-Mounted Motor

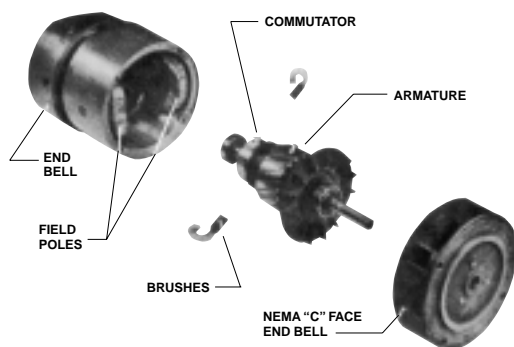


Figure 8.2, Exploded View of "Wound-Field" DC Motor

Example: At 60 Hz, a two-pole motor has a maximum speed of 60 revolutions per second, or 3600 RPM; four poles, 30 revolutions per second, or 1800 RPM; six poles, 20 revolutions per second, or 1200 RPM, etc. Thus, it is possible to vary or adjust the speed of an AC motor by varying the frequency applied.

For all intents and purposes, these "inverters" convert AC to DC and then "synthesize" a 3-phase output for the driven motor. These controllers are especially useful for using AC motors that are "special" and/or hard to replace, and when adjustable speed may be necessary. AC controllers provide speed ranges from zero to base speed (a subject that will be discussed later on in our Power Transmission 101 course).

DIRECT CURRENT (DC) MOTORS

Direct current travels in only one direction, like water through a pipe. It has no "frequency" since it does not reverse direction the way AC does. The DC motor is ideal for speed adjustments, since its speed can be simply and economically varied from base speed to zero RPM, by adjusting the voltage applied to the armature of the motor. Boston Gear's Ratiotrol DC systems employ this basic principle

In a DC motor, the rotating element is called the armature and the stationary component, the field. In an AC induction motor, power is applied to the field (stator) only. In a shunt-wound DC motor, both field and armature are energized. The armature windings are connected to commutator segments, which receive electrical power through carbon "brushes." (See Figure 8.2)



Figure 8.3, M-Series DC Motors

The application of DC power to the field of a DC motor creates a magnetic force that also passes through the armature. When DC power is applied to the armature, another magnetic field is set up which either opposes or assists the magnetic force of the field, depending on the polarity of the two fields. The commutator on the armature serves as a means of changing the direction of current flow in the conductors of the armature windings. This continuous repelling and attraction causes the armature to rotate at a speed determined by the voltage and current in the field and armature. *RATIOCONTROL* controllers change the speed of a DC shunt wound (See Figure 8.4) motor by varying the voltage supplied to the armature, while keeping the field voltage constant. In this way, the speed of a DC motor can be infinitely varied from base speed of the motor to zero RPM.

Permanent magnet (PM) (See Figure 8.5) DC motors have no field winding; they do not, therefore, require any power to energize the field. The field is a permanent magnet, which results in a motor that is the equivalent of a shunt-field motor with regard to performance, yet often smaller, lighter and less costly.

Ratiocontrol controllers can be used with either shunt-field or PM motors. PM motors are usually the better choice for the reasons mentioned above. In addition, the presence of only two wires to connect the armature leads minimizes the chance of installation errors that can result in smoking the motor, resulting in a costly problem.

APPLYING RATIOCONTROL

Several factors must be considered when selecting the best drive for an application, starting with the *type of load*.

- **Constant torque loads**, the most common type of load, require the same torque (or turning effort) at low speed as is required at high speed. Most applications fall into this category including conveyors, printing presses, agitators, etc. A constant torque drive delivers its rated torque regardless of RPM, but the horsepower varies directly with speed. For most applications, the torque requirements remain essentially constant over the speed range. Thus, the horsepower requirements decrease in direct proportion to the speed. Maximum (rated) horsepower is only acquired at maximum (base) speed. (See Figure 8.6)



Figure 8.4, Shunt Wound Motor

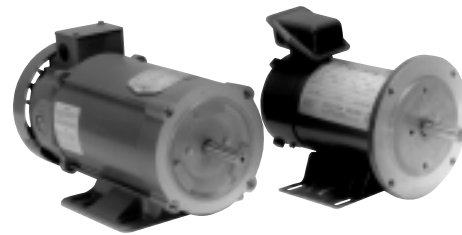


Figure 8.5, Permanent Magnet Motors

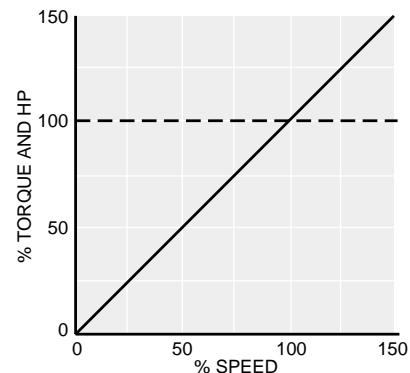


Figure 8.6, Constant Torque

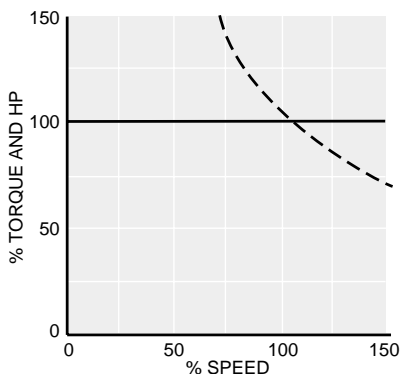


Figure 8.7, Constant Horsepower

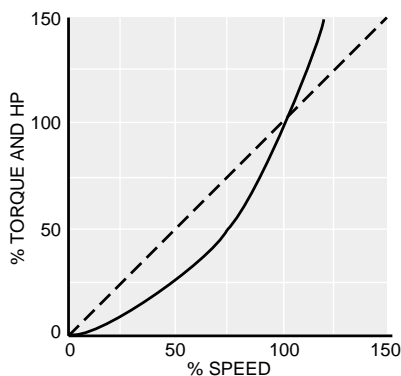


Figure 8.8, Squared Exponential Horsepower

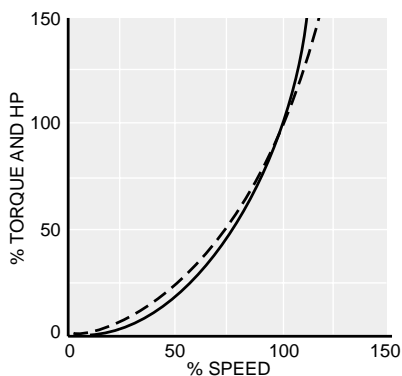


Figure 8.9, Cubed Exponential Horsepower

- Another type of load – the **constant horsepower application** – requires equal horsepower throughout its speed range. Examples of constant horsepower loads include center-driven winders and machine tools that are used to remove material. Winders or rewinds require that the product tension remain constant regardless of speed while the coil of paper, cloth, film, etc. builds up on the winder. In the case of the machine tool, heavier cuts are taken at lower speeds, necessitating more torque. (See Figure 8.7)
- Variable torque and horsepower loads require less torque at low speeds than at higher speeds, and are used with fans, blowers and centrifugal pumps. (See Figures 8.8 and 8.9)

Approximately 90% of all general industrial machines (other than fans and pumps) are constant torque systems. Accordingly, the remainder of our speed drive lesson will be dedicated to that type of system.

RATIOTROL SELECTION

Before selecting a Boston Gear Ratiotrol motor speed controller system, it is extremely helpful to know the following:

HORSEPOWER (HP) OR TORQUE

Horsepower or torque must be known to properly size the controller and motor requirements for a given application.

POWER REQUIREMENTS

Depending on the series and size, Ratiotrol systems have been designed for use on single or polyphase power of various standard voltages. As a result, it is important to check control power requirements to assure that the proper power source is available; i.e., line voltage, frequency (Hz) and phase.

SPEED RANGE

Refers to the range of speed at rated regulation, as noted in the *Performance Characteristics* section of your Boston Gear Electrical catalog. For example, a 50:1 speed range means that a 1750-RPM motor can be adjusted anywhere between 1750 and 1/50th of 1750, or 35 RPM. Below that minimum speed the motor might stall if its load status should change from near no-load to full load. However, all Ratiotrol drives can operate from the motor's base speed to zero RPM.

SPEED REGULATION

As defined by NEMA, speed regulation is the change in motor RPM from *no load* to *full load* (or, more generally, to 95%-full load). Regulation is always expressed as a percentage of base speed. The value specified for each control series assumes that all other variables (such as line voltage, temperature, etc.) are constant and within specified limits.

Example: A control having a specified system regulation of 1%, used with a 1750 RPM motor, would experience a drop in speed of 17.5 RPM at any speed when experiencing a 95% load change.

DYNAMIC BRAKING (DB)

Many reversing applications require dynamic braking to permit the maximum number of reversals for the motor being used. Dynamic Braking permits faster than normal stopping, but it is not a holding brake: once the motor and load have stopped, there is no further braking action. Additional details regarding dynamic braking are included in the Options section of your Boston Gear Electrical catalog.

REVERSING

It is important to know whether the driven machine requires bi-directional operation or whether it always “travels” in the same direction. All Ratiotrol controllers offer reversing either as a standard or optional feature.

MANUAL SWITCHING

Manual Switching refers to a manual switch, usually a toggle type, which the operator must flip up or down, or side to side, in order to start, stop or reverse a drive.

MAGNETIC SWITCHING

Magnetic Switching refers to a contactor (or relay) mounted in a controller and operated by a pushbutton (or similar pilot device) outside the controller, usually in a remote station. Magnetic switching is easily adaptable to limit switches and remote stations designed for unusual conditions such as dust, water and hazardous atmospheres.

CATALOG

CHECK!:

While the basic terms and features discussed will help you select the right motor speed controller, your Boston Gear catalog contains additional details about special features, such as: adjustable linear acceleration, master override, multi-motor, multiple-preset speeds, adjustable torque control, tach follower, tach feedback and external signal follower options.



Figure 8.10

Selection: When selecting a Ratiotrol drive or a Ratiotrol/reducer system for constant torque, first determine:

- The maximum and minimum speeds required at the input shaft of the machine.
- The torque (in.-lbs.) required at the input shaft of the machine.

Note: If HP is given at maximum speed, it should be converted to torque using the following formula:

$$T \text{ (torque)} = \text{HP} \times 63,025 \div \text{RPM max.}$$

From the selection charts in your Boston Gear catalog, pick a drive with a torque capacity equal to or greater than that required for the application.

THE RATIO-PAX SERIES

Ratiopax is the term Boston Gear uses for a simple, compact, non-modifiable enclosed DC motor speed controller used with motors ranging from 1/12 HP – 1 HP.

(See Figure 8.10)

The Ratiopax series provides a remote station-sized package offering fullwave rectification, transistorized SCR firing and IR-compensated armature feedback, combining economy and dependable performance.

The Ratiopax's clean, accessible printed circuit board solidly mounts all the components (except the front panel switch, speed-setting potentiometer and SCR's). The entire unit is housed in a rugged die-cast aluminum case measuring only 3" x 3" x 9".

Additional features include:

- Speed range: Infinitely adjustable from 0 to base speed
- Speed range at specified regulation: 20 to 1
- Regulation (no load to 95% load): 5% of base speed
- Full-wave armature rectification
- Transistorized firing circuitry
- Printed circuit construction
- Adjustable maximum speed
- Voltage feedback with IR compensation
- Automatic current limit

DCX & DCX PLUS SERIES

Ratiotrol DCX Controllers, developed as an OEM chassis system, also offer a full-featured controller in a physical package similar in size to the Ratiopax.

Enclosed, panel-mounted and open chassis versions of the DCX series – with ratings as high as 3 horsepower – offer a solution to almost any control application.

Additional features include:

- Speed range: to base speed
- Speed range at specified regulation: 30:1
- Regulation (no load to 95% load): 2%
- Full-wave power conversion
- Transient voltage protection
- DC tachometer feedback
- Automatic line voltage selection
- Adjustable current limit
- Adjustable maximum speed
- Adjustable minimum speed
- Adjustable IR compensation
- Adjustable acceleration/deceleration (with the exception of the DCX101C)
- NEMA 12 enclosed
- Ratings up to 3 horsepower. (See Figure 8.11)



Figure 8.11

BETA II AND BETA PLUS SERIES

The Beta series DC motor speed controllers represent the latest compact Ratiotrol SCR system. They are more rugged than the Ratiopax and DCX series and offer improved performance, expanded horsepower range and many other important operating and performance features.

The Beta series was designed to fill the void between the simple, economical DCX and Ratiopax and the more sophisticated VEplus and VED controllers.

In essence, Boston Gear Beta systems offer performance once available only in more sophisticated drives coupled with an economy and design simplicity approaching the Ratiopax. (See Figure 8.12)



Figure 8.12

ADDITIONAL BETA II FEATURES INCLUDE

- Horsepower range: 1/12 – 3 HP
- Speed range: Infinite
- Speed range at specified regulation: 50:1.
- Regulation (no load to 95% load): 2%.
- Full-wave rectification
- UL Listed
- CSA Approved
- TENV die-cast enclosure, gasketed
- “Washdown” models to meet NEMA 4X specifications
- NEMA 3, 4 or 12 enclosure
- Chassis and angle bracket mounting units
- User Adjustments:
 - Accel/decel time
 - Line-starting
 - Adjustable current-limit
 - DC tach feedback on unidirectional drives
 - 115/230 VAC – selectable

BETA PLUS ADDED FEATURES INCLUDED

- Horsepower range: 1/6 – 3 HP
- 4-SCR power bridge for improved motor performance and life
- Isolated regulator and feedback circuitry
- External 4-20 ma DC signal follower circuitry included
- Horsepower and AC line voltage calibration provided by jumper wires
- Bi-color LED indicator lamps signal normal operation as well as current-limit (overload) running conditions. (See Figure 8.13)



Figure 8.13

SELECTING YOUR RATIOTROL PRODUCT

Now let's apply what we have learned about Ratiotrol motor speed controllers by selecting a controller for a typical application. First, let's review the following givens:

- Application: horizontal conveyor
- Torque required at conveyor shaft: 235 in.-lbs
- Speeds required at driven shaft: 10 to 58 RPM
- Load type: constant torque (the torque remains the same throughout the speed range)
- Line Power: 115 VAC, single phase, 60 Hz
- Reversing required occasionally
- Ambient conditions: clean, dry, temperature 70-100-degrees F
- Drive type desired: right-angle gear motor

Step 1: Selection of the reducer/motor system. The customer's requirements regarding performance, operators devices and/or options will determine the best control series to recommend.

Step 2: With known requirements of 235 in.-lbs. at 58 RPM, use the following formula to **determine the estimated horsepower:**

$$\begin{aligned} & Tq \text{ (in.-lbs.)} \times \text{rpm} \div 63,025, \text{ or} \\ & 235 \times 58 \div 63,025 = 0.216\text{HP output} \end{aligned}$$

Step 3: Refer to the Reducer Selection Chart in the Worm Gear Drives catalog.

Step 4: Select a suitable Ratiotrol controller/motor combination using the Selection Chart from the Boston Gear Electrical Products catalog.

Important: Once you have selected the system HP and the motor required, the functional, mechanical and physical requirements of the application must be analyzed. At that point, the controller can be selected from the information included on the **RATIOTROL SYSTEMS** charts shown in the Boston Gear Electrical catalog.

Step 5: Depending on the customer's size, functionality, and other requirements, any one of the previously mentioned controllers could be selected.



Figure 8.14, VED Series Controllers

VED SERIES DC ADJUSTABLE SPEED CONTROLLERS

VED controllers are high performance, microprocessor-based, software-configured, packaged drive units that represent a significant advance in single-phase control design. They offer advantages formerly possible only with complex and expensive external digital control loops. Standard VED features include:

- Pre-tuned control algorithms for speed and current regulators
- Digital set-up and troubleshooting
- Complete self-diagnostic capabilities

Optional features – which make the VED series an ideal choice for a broad range of industrial applications – include:

- Remote interrogation
- Digital speed input and feedback
- Accurate digital speed regulation
- Serial communication for direct control by programmable logic controllers and computers

VED units include conversion of AC line power to DC for adjustable speed armature control of shunt-wound and permanent magnet field DC motors. (See Figure 8.14)

MODEL TYPES

VED units are offered in both open chassis and enclosed configuration in 26 standard models. The basic, open chassis models – VED100 (for 115V AC power) and VED300 (for 230 V AC power) – form the nucleus of all the other models. The other 24 are assembled from the two basic models using the appropriate option kits, which can be ordered factory-installed or easily added in the field.

LOCAL CONTROL OPERATION

Local control, enclosed, packaged models are provided with an integral cover-mounted operator control panel. Included are membrane push switches for all control functions and an LCD display that indicates important operational data.

REMOTE CONTROL OPERATION

Enclosed, packaged remote control models have a blank cover mounted in the space reserved for the operator control panel. Because the cover and operator control panels are dimensionally interchangeable, the controller may be easily field-converted from local to remote control.

VEplus SERIES ADJUSTABLE SPEED CONTROLLERS

The VEplus Series incorporates the latest technology in solid state design. The result: the most versatile, rugged DC motor speed controllers available today. Its many features make the VEplus controller precise, adaptable and rugged – ideal for even the fussiest application. Features include:

- VEplus controllers are available in 1/6 to 1 HP for 115VAC single phase 50/60 Hz and 1 to 5 HP for 230VAC single phase power.
- VEplus controllers can follow signals from other upstream drives, be commanded to change speeds automatically, start and stop on demand, reverse, start smoothly, and stop very quickly.
- Option combinations permit the systems to follow temperature changes, weight recorders, computer or PC commands.
- All controllers are CSA-approved, UL listed – increasingly important factors in today's marketplace.
- Speed Range: Indefinitely adjustable from zero to base speed.
- Speed Range: Full Load, Continuous Operation: 50 to 1.
- Regulation, 95% Load Change: 2% of motor base speed.
- Efficiency (Maximum Speed):
 - Controller, SCR Regulators – 99%
 - Complete drive with motor – 85%

(See Figure 8.15)

ADDITIONAL FEATURES:

- Full wave armature supply: 4-SCR 600 PIV power bridge, on all controllers.
- Armature voltage feedback and IR compensation for maximum speed stability and regulation.



Figure 8.15

- Modular construction: Four(4) printed circuit boards and encapsulated bridge.
- Plug-in input option boards.
- Plug-in feedback options.
- Transient voltage protection utilizing metal oxide varistors.
- Lightweight, heavy-duty, totally enclosed aluminum die cast housing, light gray epoxy finish, readily convertible to NEMA 3, 4 and 12.
- Circuit breaker provides instantaneous peak load tripping and short circuit protection (serves as AC on-off switch).
- Motor contactor: disconnects motor armature, incorporates "dry switching" for maximum life. Prevents automatic restart after power interruption. Provides under voltage protection.
- Load monitor circuit: electronically monitors motor armature current and stops drive if the load exceeds 120% for 80 seconds. Provides protection equivalent to a motor thermostat.
- Adjustments:
 - Speed 0-100% of motor base speed
 - Maximum speed: 60-100% of base speed
 - Minimum speed: 0-30% of base speed
 - Current limit: 50-150% full load torque
- UL listed
 - Low voltage pilot circuit: 24VDC
 - AC power disconnect: circuit breaker
 - Mandatory restart
 - Armature contactor

Now let's quickly review the general characteristics of Boston Gear's Ratiotrol systems, keeping in mind why you would suggest one rather than another for a particular application or customer.

- Ratiopax: non-modifiable.
- BETA II, BETAplus: limited modifications and options.
- VEplus, VED: many options, field installable.

OPTION KITS

Option kits are described briefly in Boston Gear's Electrical Products catalog. The most popular options are dynamic braking, reversing (manual as well as magnetic), open chassis construction, jogging, master override, adjustable linear acceleration, multiple preset speeds, torque-taper, tach follower, tach feedback, external signal follower and special enclosures.

Keypoints

- Boston Gear carries a wide range of single phase DC controls
- Ratiotrol controllers have a long history of quality and dependability
- Horsepower ranges grow 1/12 to 5 in. single phase
- Engineering staff at Boston Gear can help with any application problem
- All ratiotrol controllers carry a full 2 year warranty

Quiz

CLICK HERE or visit <http://www.bostongear.com/quiz> to take the quiz

QUIZ