AC and DC Variable Speed Drives Application Considerations

Application Solution

Introduction

Knowing what controller/motor package to use in a given situation is just one of the subjects covered in this overview of AC and DC drive application considerations. Published originally as a direct mail piece for distribution use, it has been updated with additional information on drive selection to make it a more useful reference and training tool. This has been previously released as publication D-7151, but is updated here.

This information also appears in the introduction section of the Standard Drives Catalog (D-406).

Drive products support diverse applications with a wide variety of products. AC drives serve processing needs and industrial applications such as fans, pumps, mixers, conveyors, and extruders, plus many more. DC drives control processing equipment such as for sheet metal, material handling, and center winders/unwinders. Any drive featured in this publication will provide some form of motor speed regulation and variable speed operation. Within these categories, we offer a broad spectrum of horsepower ranges, drive interconnectivity capabilities, and flexibilities.

When selecting a drive for your application, a major consideration is whether to use an AC or DC drive. Either drive is practical from the following standpoints:

- Wide constant horsepower speed range
- Proven performance with matched drive/motor packages
- High speed regulation capabilities
- Worldwide sales and technical support

The considerations involved in choosing either AC or DC drives are discussed in the following section.

Application Discussion

Which drive is right for you?

Your choice depends on many application-specific factors such as ambient conditions, type of loads, duty cycle, maintenance accessibility, horsepower range, sequencing, and more. The following brief guidelines have been developed to provide you with a basic understanding of the differences between AC and DC drive technologies. If you have specific questions, or require application/selection assistance, please contact your nearest Reliance Electric Sales Office or authorized Reliance Distributor.

AC DRIVE CHARACTERISTICS

- AC drives utilize a solid-state adjustable frequency inverter which adjusts frequency and voltage for varying the speed of an otherwise, conventional fixed speed AC motor. This is achieved through Pulse-Width Modulation (PWM) of the drive output to the motors.
- Voltage and frequency are maintained at a constant relationship at any motor speed to maintain a constant torque. This is known as the volts per hertz ratio.
- Integrated drive/motor packages available.

Standard AC Drives are often the best choice when:

- The environment surrounding the AC motor is corrosive, potentially explosive, or very wet, and demands special enclosures such as explosion-proof, washdown, X-Extra Tough, etc.
- Motors are likely to receive little regular maintenance due to inaccessibility of the motor or poor maintenance practices.
- The motor must be small in size and weigh as little as possible.

- Motor speeds can reach 10,000 RPM.
- Multiple motors are operated at the same speed by a single drive.
- Speed regulation of 1 % is acceptable.
- Existing fixed speed (Design B) AC motors can possibly be used.
- A UL listed AC drive and motor package for hazardous classified locations is required.
- C-E compliance is required at 2 HP or less.

Additionally, Vector AC Drives are often the best choice for:

- Applications requiring full load torque at zero speed.
- Fast changing loads.
- Tight speed regulation.
- Coordinated speed control for multiple drive axes.
- Applications requiring increased starting torque.
- Precise closed loop speed regulation (to 0.01% and less) is required.
- High dynamic response.
- Web processes, material handling sorter conveyors, metering pumps, extruders, and test stands.

DC DRIVE CHARACTERISTICS

- DC drives utilize a converter to transform AC current into DC current which is then fed to the DC motor which is designed for adjustable speed operation. Speed changes are made by increasing or decreasing the amount of DC voltage fed to the motor from the drive.
- Usually offer the lowest cost for medium and high HP applications.

DC Drives are often the best choice when:

- Environmental conditions surrounding the DC motor are reasonably clean, dry, and allow the use of DPG, DPG-FV, TENV, or TEFC motor enclosures.
- The application requires a wide range of changing loads such as center driven winders.
- Motor speeds can reach 2500 RPM.
- Starting torques are greater than 150% or unpredictable.
- Application HP requirements are medium to large.

Drive Comparison Chart

Use this chart as a quick, basic reference guide to help you determine the drive best suited for your application needs.

	Standard DC	V/Hz AC	Sensorless Vector AC	Flex Vector AC
Speed Regulation	0.01% (2)	1%	.5%	.01%
Speed Range	100:1	10:1	120:1	>1000:1
Encoder/Tachometer Required?	Yes/No	No	No	Yes/No
Constant HP Range	4:1	2:1	4:1	4:1
Starting Torque	150%	110%	150%	150%
High-Speed Capability (1)	<3000	<6000	<6000	<6000
Regeneration	Line	Snubber/Line	Snubber/Line	Snubber/Line
Dynamic Braking w/o Regulation	Yes	No	No	No

(1) Speed rating in RPM with standard motors.
(2) Dependent on encoder or tachometer used.

AC MOTOR SELECTION

Various types of AC induction motors are suitable for operation with AC drives. It is essential that the user understand the nature of the application in terms of load characteristics, speed range, and drive requirements, as they relate to the AC drive system, so that the proper combination of motor and drive can be selected for optimum performance.

The following motor performance graphs represent the maximum continuous capability of the respective motors when operated with AC drives. These guidelines are conservative and are based upon full rated conditions (i.e., full horsepower requirements operating continually in a 40°C ambient. Full rated input voltage is assumed). Since motors are frequently sized larger by the user than the actual horsepower required to provide a performance safety margin, the actual motor performance may be less than 100% full load capability. This should be considered in using the data on the graphs.

Most standard AC motors are designed to operate at a fixed, rated frequency and speed. At this fixed speed, the built-in cooling system will keep the motor from overheating. When operated as an adjustable speed device at slower speeds, the motor cooling action will be reduced. On such applications, the motor may need to be a motor specifically designed for AC drive operation such as the RPM AC motor. RPM AC motors offer premium performance on Reliance AC drives

SIZING THE AC MOTOR

The following procedure gives a conservative, engineering-based approach for sizing and selecting various AC motors for use with the AC drive.

WARNING

MACHINERY BUILDERS AND/OR USERS ARE RESPONSIBLE FOR INSURING THAT ALL DRIVE TRAIN MECHANISMS, THE DRIVEN MACHINE, AND PROCESS MATERIAL ARE CAPABLE OF SAFE OPERATION AT THE MAXIMUM SPEED AT WHICH THE MACHINE WILL OPERATE. FAILURE TO OBSERVE THESE PRECAUTIONS COULD RESULT IN BODILY INJURY.

1. Determine the drive motor output horsepower and continuous torque over the total speed range and the starting torque requirements.
2. Select the type of motor and drive.
3. Using the following graphs for the type of motor selected, confirm that the required load torque from the motor selected falls within the "acceptable region" of the graph.

GRAPHS 1 THROUGH 4 SHOW TYPICAL CONSTANT TORQUE SPEED RANGE CURVES WITH GENERAL PURPOSE REGULATION - GV3000/SE (With Parameter P.048 Set For"U-H") AND SP500.

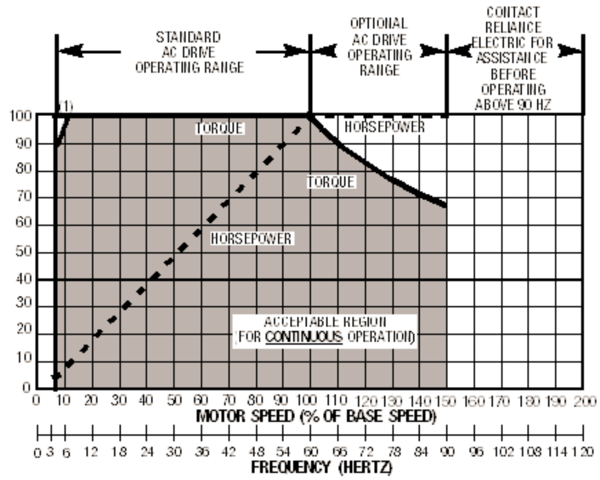
GRAPHS 1 AND 2 ARE ALSO TYPICAL FOR BOTH THE SP100 AND SP200 DRIVES.

Continuous motor performance for constant torque to base speed and constant horsepower above base speed. Wider constant torque ranges and/or horsepowers are available but application assistance will be required.

Graph 1. 10:1 CONSTANT TORQUE

This graph applies for the following motors used with an AC PWM drive:

- VXS vector-ready motors to 10 HP.
- VXS inverter duty motors to 150 HP.
- Explosion-proof energy efficient XE motors 1/3-150 HP (check motor nameplate to verify CT rating).
- TENV-EM and TENV EMT motors (for use with SP100 drives).

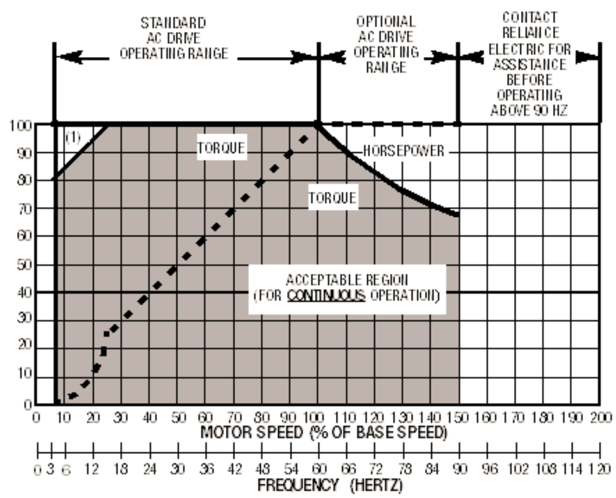


(1) Continuous operation in this region is not recommended and may result in reduced motor life.

Graph 2. 4:1 CONSTANT TORQUE

This graph applies for the following motors used with an AC PWM drive:

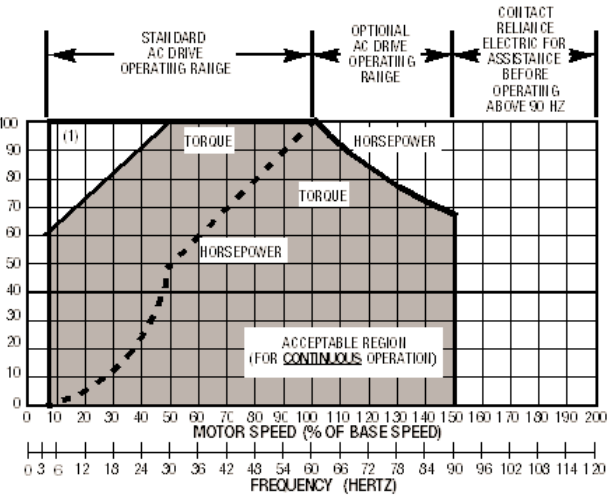
- TENV and TEFC energy and premium efficient motors 1-350 HP.
- TENV-EZ easy-clean washdown duty motors.
- Explosion proof energy-efficient XE motors 1 1/2 - 150 HP (check motor nameplate to verify CT ratio).



(1) Continuous operation in this region is not recommended and may result in reduced motor life.

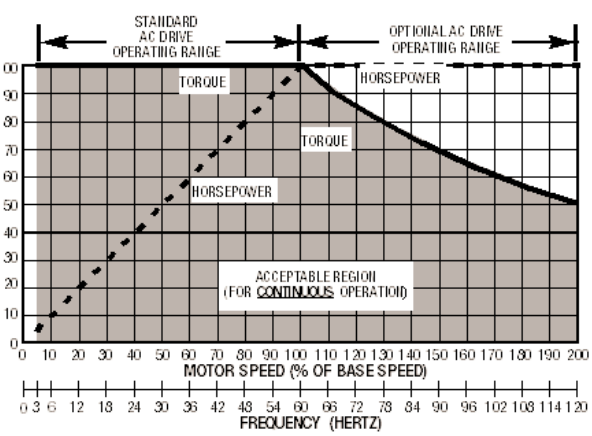
Graph 3. 2:1 CONSTANT TORQUE

For use with explosion-proof energy efficient XE motors 1 1/2 - 150 HP (check motor nameplate to verify CT ratio).

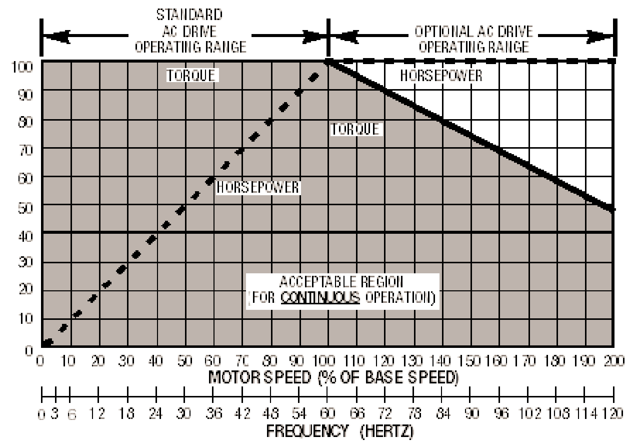


(1) Continuous operation in this region is not recommended and may result in reduced motor life.

Graph 4. Reliance RPM AC Motors (TENV, TEA0-BC and DPFV Enclosures) and VSM500 Integrated Drive/Motor Packages



Graph 5. Reliance Vector Duty Induction Motors (TENV, TEA0-BC and DPG-FV Enclosures) with Encoder Feedback



SIZING THE AC DRIVE

The capabilities of the AC drive are determined by its output current rating. The drive chosen must have a continuous current rating equal to or more than the maximum motor load current. Be sure to consider all loads including startup acceleration.

Single Motor and Drive Applications

NEMA Design B motors, will generally perform as shown in the engineering data section. Note that all references to HP are for single motor, standard NEMA B, 1.0 service factor, non-explosion proof induction motors only.

General Sizing Method for Use with Multiple Induction Motors

To size the six to 60 Hz drive for multiple motor applications or for any applications for six to 120 Hz, the following procedure is used.

1. Examine each motor to be driven and determine motor full-load amperes at line voltage. Determine the total full-load current requirements for all motor(s) to be controlled by the drive.
2. To the current determined in step one, add the high currents of any overloads which may exist such as acceleration, peak load, etc., - and determine maximum short-term load at line voltage. (Note: motor acceleration is by linear timed-rate acceleration control. Therefore, locked-rotor amperes normally associated with across-the-line starting of AC motors are not encountered.)
3. Select the AC drive rating from the table with a current

capacity that will support the required currents as calculated in the previous steps.

4. If other than NEMA Design B - 1.0 Service Factor Induction motors are to be used, or if explosion proof listed motors are required contact your Reliance Electric sales office or Standard Drives application engineer for application assistance.

AC DRIVE LEAD LENGTH

Standard AC drives utilize IGBT technology for rapid switching of PWM devices to produce accurate sinusoidal drive outputs. Typically operating at carrier frequencies of 8 kHz, low motor acoustic noise is achieved. However, PWM devices can also cause undesirable side effects such as motor stress, high peak voltage and possible reflected waves that exacerbate the peak voltage problems.

Reliance Electric's matching drive/motor packages offer superior design and proven performance. All drive/motor combinations have been tested for dynamic stability. When applied properly, motor stress effects and high peak voltage should be minimal. The table below highlights maximum motor lead lengths allowed without external filtering.

Maximum Lead Length* (Feet)

	230VAC	460VAC	575VAC
GV3000/SE	500	500	N/A
SP500	500	250	150
SP200	100	100	N/A

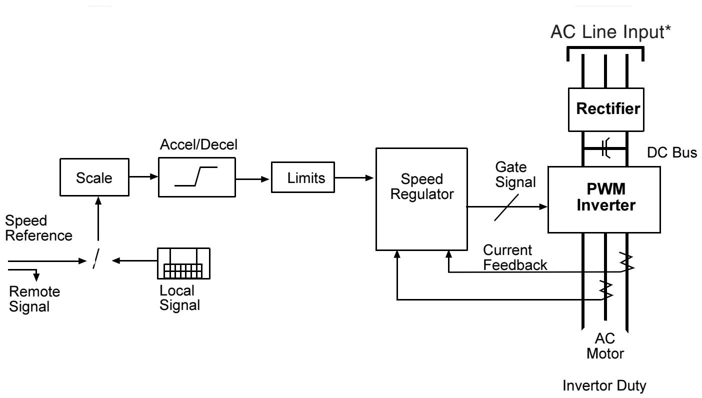
*Maximum lead lengths vary also with carrier frequencies and horsepower ratings. Additional external filters can be specified to extend lead lengths. Please see Application Note D-154 for more detailed information.

Open loop AC PWM Control Block Diagram

A. The user supplies a speed reference to the drive. There is always a choice between supplying a remote analog reference or a local reference via keypad selection.

B. The speed reference may be conditioned for acceleration and deceleration rates as well as maximum and minimum speed settings.

Open Loop AC PWM Control Block Diagram

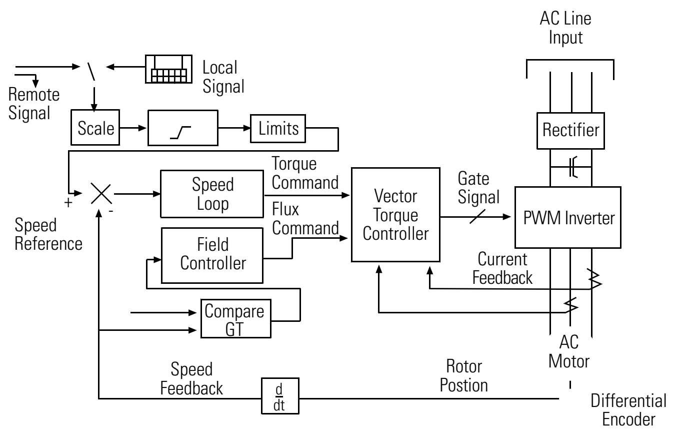


* Can be single phase input depending upon the type of drive selected.

C. The speed regulator section provides gate pulses to the continually alternating Insulated Gate Bipolar Transistors (IGBTs). The relative on-to-off times for pulses to be successively fired is continually alternating so as to create a sinusoidal voltage pattern at the IGBT output. The wave frequency is altered to produce variable speed outputs.

D. Rectified DC voltage (or DC bus supply voltage) is the source for the IGBTs. They are arranged in three pairs whose wave patterns are each 120 degrees apart. The power output signals to the motor create sinusoidal wave patterns to each phase. Wave frequency changes to change the motor's speed.

AC PWM Vector Control Block Diagram



AC PWM VECTOR Control Block Diagram

A. The user supplies a speed reference to the drive. There is always a choice among supplying a remote analog reference or local reference via keypad selection. Also, it could be supplied across a network interface if an optional network interface card is included with the drive.

B. The speed reference may be conditioned for acceleration and deceleration rates as well as maximum and minimum speed settings.

C. The conditioned speed reference is compared to a speed feed back signal as supplied by the motor encoder. Any error signal between the reference and the feedback signal is amplified in this outer (or major) control loop via proportional and integral gains. Stability adjustments change the gain of this control loop to match the desired dynamic response. The resulting signal is applied as a reference to the current regulator. Motor current will provide torque, which will in turn change the motor speed to satisfy this outer loop, driving its error to zero.

D. This inner current control loop receives a reference from the speed loop. This reference is compared to current feedback from the motor. Any error is amplified and used to change the relative on and off times for gate pulses to the continually alternating Insulated Gate Bipolar Transistors (IGBTs). The relative on-to-off times for pulses to be successively fired is continually alternating so as to create a sinusoidal voltage pattern at the IGBT output. The wave frequency and its amplitude are altered to respectively produce variable speed and torque outputs.

E. As an alternative, vector operation without encoder feedback, called sensorless vector mode, is also available and discussed below.

F. Rectified DC voltage (or DC bus supply voltage) is the source for the IGBTs. They are arranged in three pairs whose wave patterns are each 120 degrees apart. The power output signals to the motor create sinusoidal wave patterns to each phase. Wave frequency changes to change the motor's speed.

G. Vector drives provide a way to regulate field supply voltage or current. These drives have the capability to limit the flux or field command and effect a field weakening condition to allow extended speed operation. This can be seen as the optional AC drive operating range in the motor speed-torque curves.

Sensorless vector operation, which is used to achieve dynamic speed and torque and control without a speed feedback device, works as follows.

A. The current feedback from a motor can be broken into its components: magnetizing and torque producing currents. Picture these as the legs of a right triangle, with the actual or measured current as the hypotenuse.

B. The magnetizing current can be shown as equivalent to the motor's no-load current. (Less windage and friction losses). This is a function of the motor's rotor design and is constant.

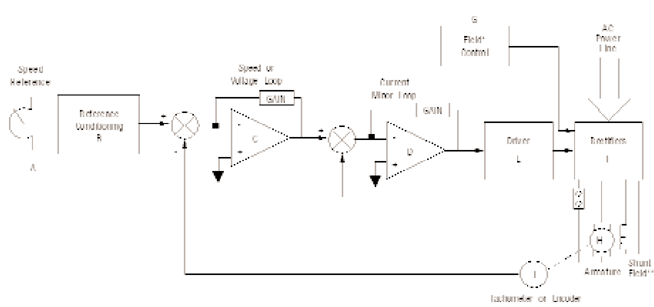
C. The torque producing current can be measured based on knowing item B. Furthermore, it can be demonstrated that motor slip and torque are related. This means that a particular load current measurement at a given commanded speed will be used to calculate the motor's slip at that moment. This will provide an accurate determination of actual motor speed.

D. Based on the actual vs. desired speed, the reference is continually adjusted to get the proper speed given the calculated slip.

E. This method of control will provide speed regulation to 0.5% on a steady state basis. Operation at or near zero speed is possible, but accuracy falls off because slip measurement at low frequencies becomes more difficult to measure.

For further reading on the basics of operation of vector control, please refer to D-7161, Vector Operation Basics.

How A Phase Controlled DC Drive Works



* If drive is equipped with motor field control hardware or software.

** If motor has a wound field (not permanent magnet).

Items A-I in this block diagram illustrate the basic functional blocks of a DC drive.

A. The user supplies a speed command to the drive.

B. The speed reference may be conditioned for acceleration and deceleration rate, as well as maximum and minimum speed settings.

C. The conditioned speed reference is compared to the voltage (voltage regulator) or speed (speed regulator using a tachometer) feedback signal from the motor. Any error between the reference and feedback is amplified in this outer (or "major") control loop and applied as a reference to the current regulator. Motor current will provide torque which will in turn change the motor voltage and/or speed to satisfy this outer loop, driving its error to zero. Stability adjustments change the gain of this control loop to match the desired dynamic response of the motor and load.

D. This inner (or "minor") current control loop receives a reference from the speed or voltage outer loop. This reference is compared to current feedback from the motor. Any error is amplified and used to change the thyristors' firing angle. This causes a change in current flow in the motor to satisfy the current loop, driving its error to zero. Some drives permit stability adjustments which change the gain of this control loop to match the electrical characteristics of the motor armature.
The inner current loop provides smooth drive performance and current limit capability.

E. The driver section of the regulator provides gate pulses to the thyristors that are synchronized to the power line phasing. The firing angle of the thyristors is determined from the current loop output and operating conditions such as the counter EMF of the armature.

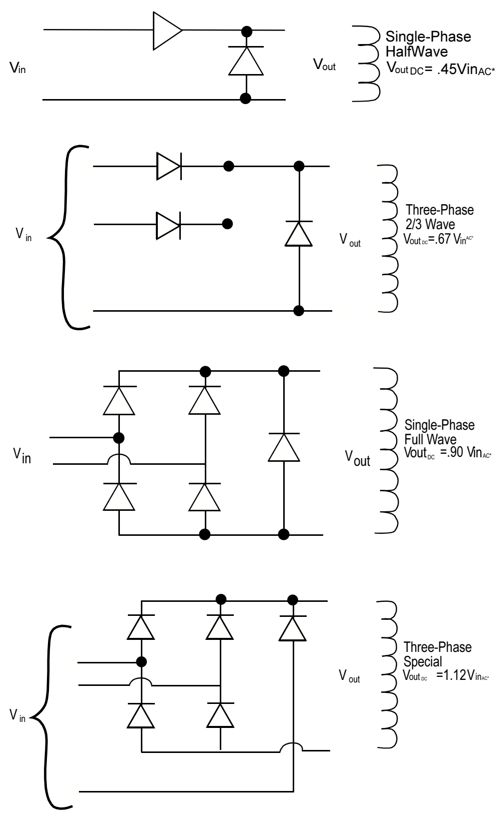
F. The AC line power is converted to DC by the rectifiers in the power bridge. Phase controlled drives have some complement of thyristors, and sometimes diodes, depending on the type of bridge.

G. Some drives provide a way to regulate field supply voltage or current. These drives have regulator functionality to accomplish this.

H. DC motor armature.

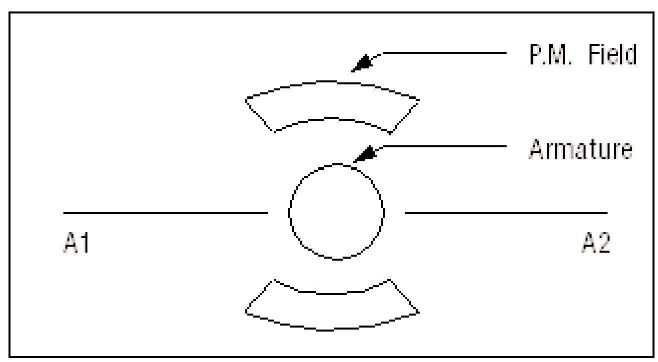
I. Tachometer or encoder if supplied.

Field Supply Bridge Types



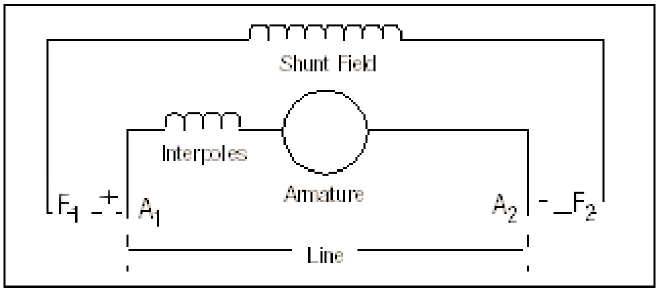
DC MOTOR TYPES

The following section provides descriptions of the three most common types of DC motors used with Reliance DC Drives.



Permanent Magnet DC Motor

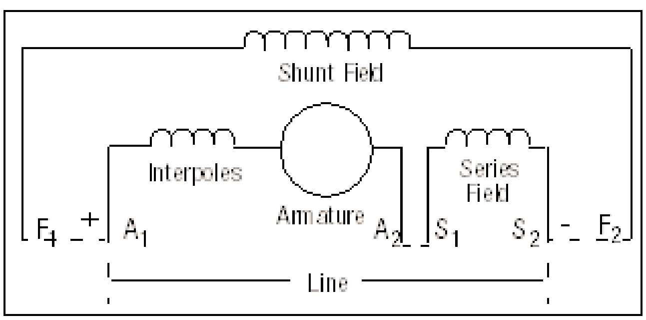
Permanent magnet motors have a conventional wound armature with commutator, brushes, and a permanent magnet field. This motor has excellent starting torques but speed regulation is less accurate than for compound motors. However, the speed regulation can be improved with various designs, such as corresponding lower rated torques for a given frame. Because of the permanent field, motor losses are less with better operating efficiencies. These motors can be dynamically braked and reversed at reduced armature voltage (10%) but should not be plug reversed with full armature voltage. Reversing current cannot exceed the full load armature current.



Straight Shunt Wound DC Motor

Shunt wound motors with the armature shunted across the field offer relatively flat speed-torque characteristics. Combined with inherently controlled no-load speed, this provides good speed regulation over wide load ranges. While the starting torque is comparatively lower than the other DC winding types, shunt wound motors offer simplified control for reversing and regenerative service.

Stabilized Shunt Wound DC Motor

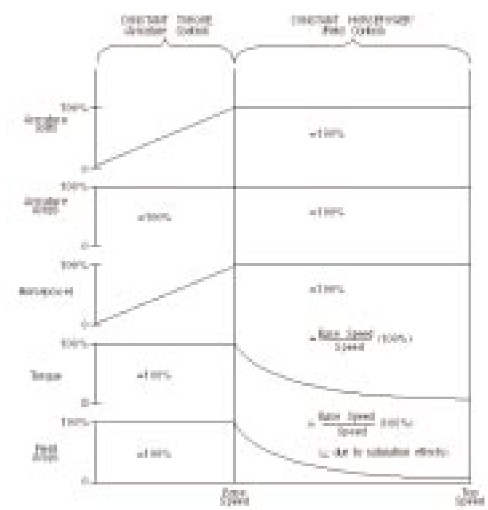


Stabilized shunt motors utilize a field winding in series with the armature in addition to the shunt field to obtain a compromise in performance between a series and shunt type motor. This type offers a combination of good starting torque and feed stability.

Approximate constant torque speed ranges of Reliance DC motors used with Reliance DC drive controllers.

Enclosure	Constant Torque Speed Range
DPG	60-100%
DPFV	1-100%
DPSV	1-100%
TENV	5-100%
TEFC	60-100%
TEAO	5-100%
TEAAC	5-100%
TEWAC	5-100%

DC Motor Full Load Operating Characteristic



NOTE: This material is not intended to provide operational instructions. Appropriate Reliance Electric Drives instruction manuals precautions should be studied prior to installation, operation, or maintenance of equipment.

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