EMERSON™
Industrial Automation

The Application Note is pertinent to the Unidrive SP, Commander GP20 and Affinity Family

RFC Mode
(Rotor Flux Control)

This application note will attempt to explain and clarify what is called rotor flux control of an ac induction motor. In order to do this, it is important to understand all of the available control schemes and where and why they should be used. The currently available control modes for ac induction motors are:

1. Open Loop, Fixed Volts / Hz Control
2. Open Loop Vector Control
3. Closed Loop Vector Control
4. Rotor Flux Control

The Commander GP20 and Affinity can operate in modes 1, 2 and 4 above while the UnidriveSP can operate in all 4 modes. The major difference is that mode 3 (Closed Loop Vector Control) requires a motor mounted speed feedback device (like an encoder). Note that the block diagrams are in a very simplified form.

Mode 1 - Open Loop, fixed Volts / Hz Control

This is the simplest control mode of all. The drive generates a linear Volts / Hz output where the output voltage and frequency are held at an exact ratio to one another. The drive controls output current by controlling the output of the acceleration / deceleration circuit. It is what is known as a spill-over regulator (after the fact regulation) which basically means that the drive has to "see" a current overload or an over voltage condition before it can respond to it. When an output overload occurs, the current limit controller will "pull" down the output of the accel/ decel circuit in an attempt to reduce the output load. In the event of a regenerative condition (load is over hauled) the drive will try to limit the regenerated energy (and thus the dc bus voltage) by increasing the output frequency. The "tell tale" sign of this occurrence is that the input speed (frequency) reference (#1.03) is not equal to the output frequency reference of the acceleration / deceleration circuit (#2.01). If the drive parameters are not adjusted "well" and for the application, drive trips can be a real nuisance. This is the main reason this scheme is poorly suited for highly dynamic applications (i.e. very fast acceleration, deceleration). Centrifugal Pumps and Fan applications (and any other applications requiring low starting torque) are ideal for this type control. There is no speed feedback used in this mode. Achievable speed regulation is on the order of 2 - 3%.
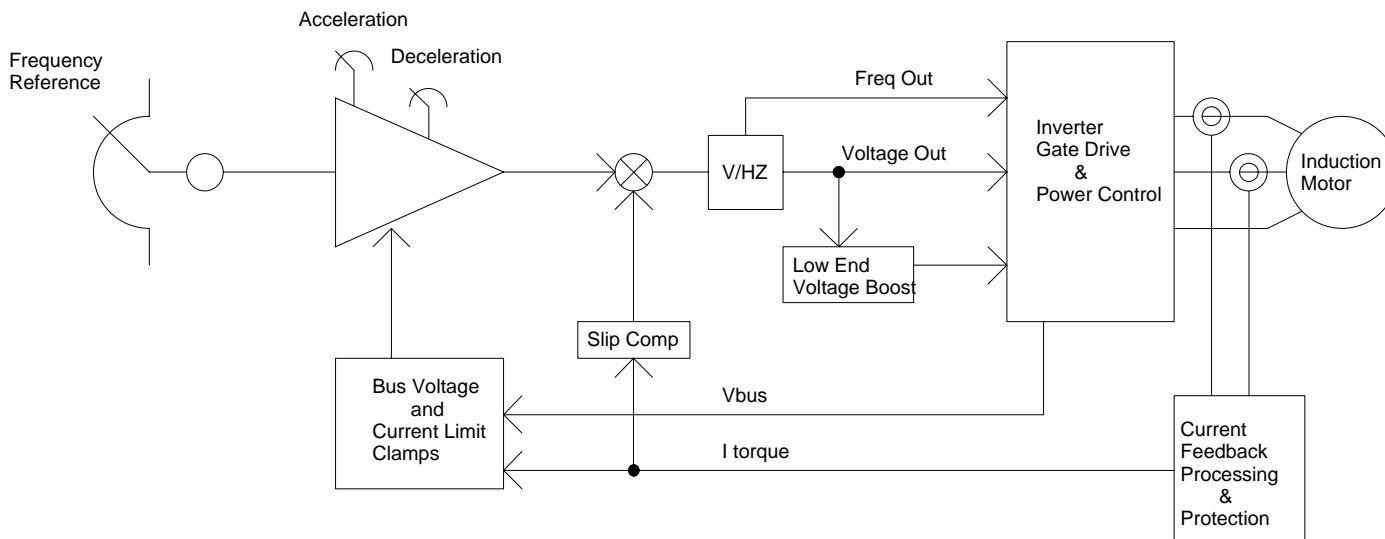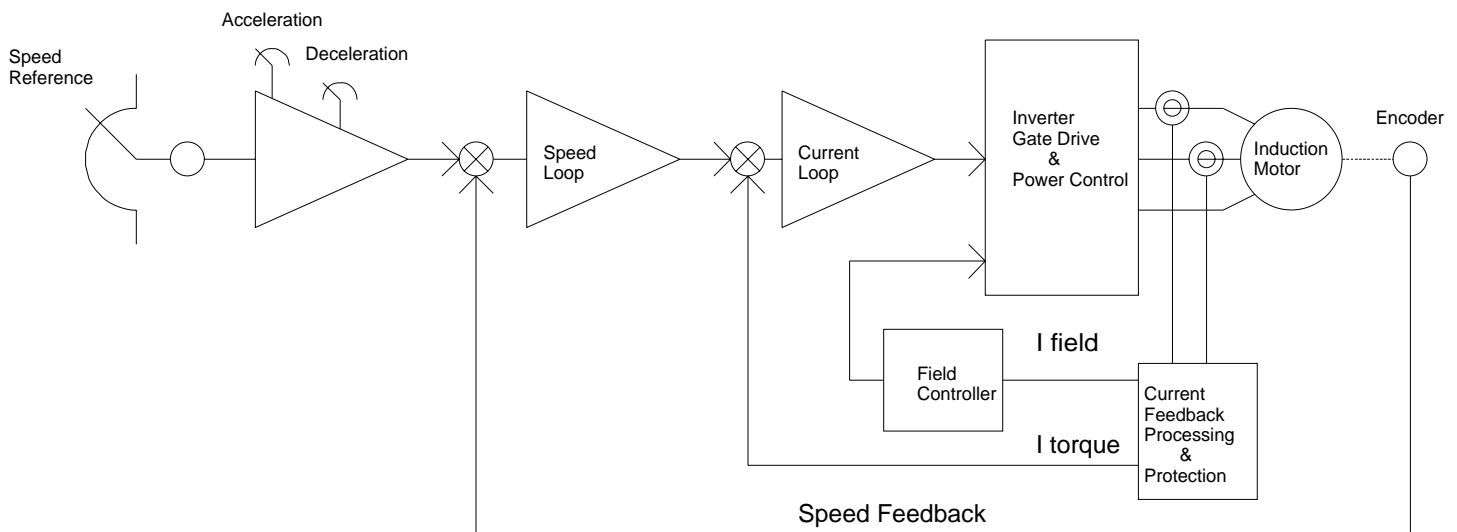
Mode 2 - Open Loop Vector Control

This mode is an enhanced version of Open Loop, Fixed Volts / Hz Control scheme. The main difference is that in this mode the drive controls the magnetizing (or field) current in the motor based on data the drive acquires from the motor during an "auto tune" test. This allows the drive to produce much better starting torque in the motor than can be achieved in the simple open loop, fixed Volts/Hz control scheme. As shown below, the main difference between the block diagram above for open loop, fixed Volts/Hz control scheme and this one are the blocks for controlling the motor torque producing and field producing currents. There is no speed feedback used in this mode. This mode is suitable for use on machines that require full load start torque and around a 30:1 speed range (with good auto tuning) like extruders, compressors and conveyors. Achievable speed regulation is on the order of 1%.
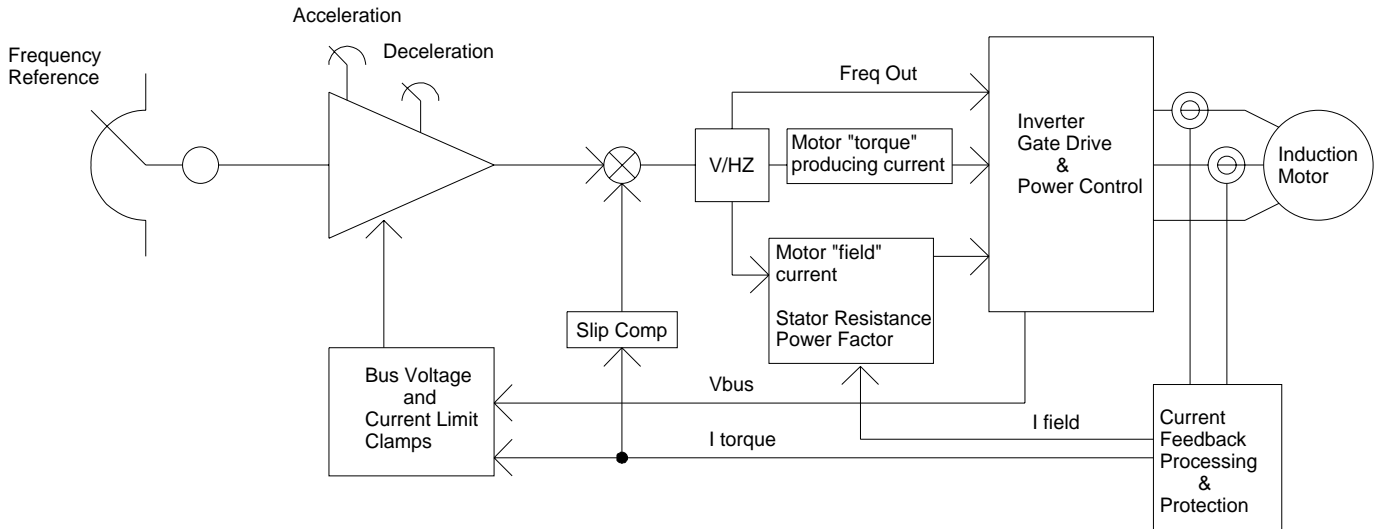

Mode 3 - Closed Loop Vector Control

From the block diagram below, it can be seen that it is quite different from the two previous diagrams. In this mode there is an inner current loop, which precisely controls the motor currents (both field and torque producing) and an outer speed loop which with the use of a motor mounted encoder (or other speed sensing device) precisely controls the motor speed. When tuned properly using the motor data and the auto tune utilities, this mode of operation provides excellent dynamic performance. This mode is suitable for use on machines that require full load torque control right down to zero speed. Achievable speed regulation is on the order of 0.01%. Applications include process lines, elevators, winches and any application requiring precise and tight speed and torque regulation.

Mode 4 – Rotor Flux Control

The block diagram for the Rotor flux Control is very much similar to the Closed Loop Vector Control with the exception that there is no physical encoder feedback device. Instead, there is a complex motor simulator (in software) that uses the motor phase voltages, currents , motor nameplate information and parameters generated by the auto tune utilities to estimate the rotor speed of the motor. It then uses this rotor speed for drive feedback. In this manner it allows the control system to use a true inner current loop and outer speed loop just like the closed loop vector control. Achievable speed regulation is on the order of 0.5%. One should keep in mind that although this control scheme does provide excellent dynamic response, speed regulation and a wide full load speed range (> 50: 1) it should not be used in applications requiring true vector control with encoder feedback.
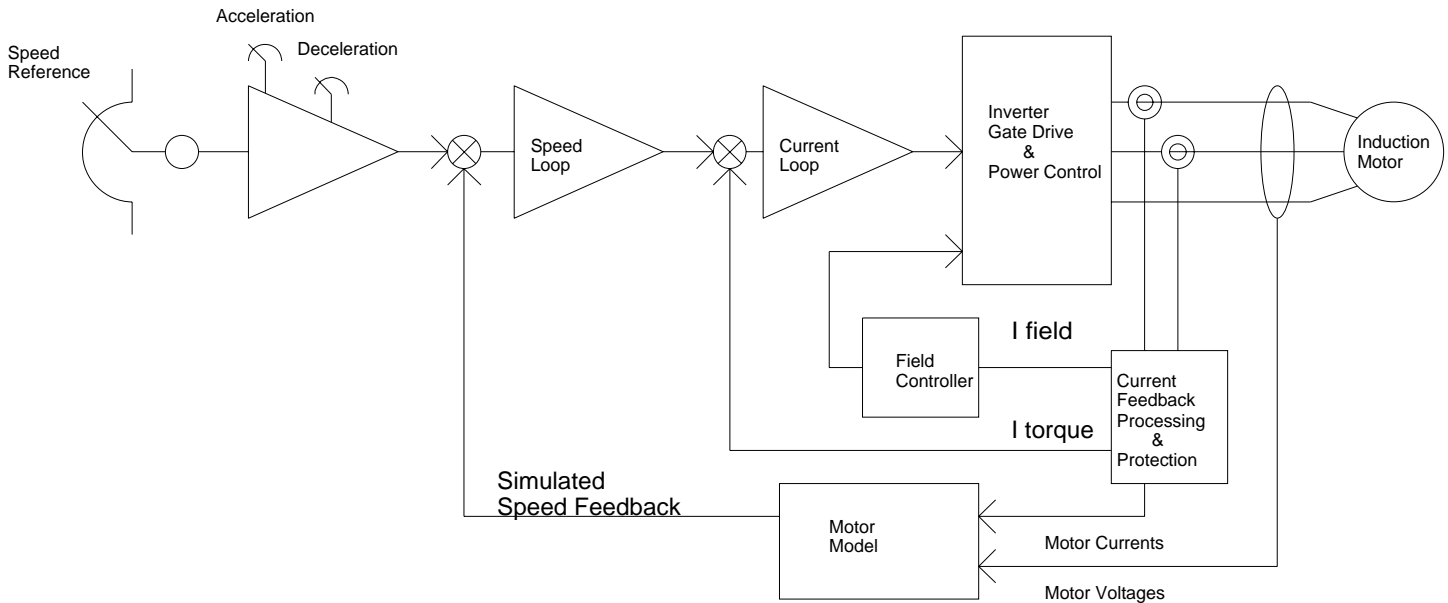

When Should RFC Mode be used?

With the exception of non-motor loads and multi-motor applications which typically would use open loop, fixed Volts/Hz control, all other open loop applications can benefit from the merits of rotor flux control. In examining the block diagrams, the most significant difference between the open loop control modes (#1 and #2) and the closed loop and RFC control modes (#4 and #3) is the inner current loop.

Open loop Volts/Hz controllers generate an output voltage (and frequency) which when applied to the motor windings produces current. This current produces a rotating magnetic field in the motor (proportional to the frequency) which causes the motor to rotate at that speed. Unfortunately at light loads and low speeds (frequencies), a phenomenon know as "dwell error distortion" (due to transistor switching) causes this current to be slightly distorted. The result of this is a slightly distorted rotating magnetic field and thus some uncontrolled torque ripple. Since the system is unloaded, this torque ripple can cause oscillation in the motor speed. Lack of damping (load) in the system can lead to severe oscillations and ultimately overvoltage (or overcurrent) trips. This phenomenon normally is not seen very often in motor drive systems less than 30HP, above that the probability of its occurrence increases with HP. Adding load can eliminate the problem but in many cases is not possible. Many drives employ compensation techniques which minimize the effects of dwell error distortion but it is not perfect and cannot correct all instances.

Closed loop and RFC control modes have inner current loop controllers which precisely control the current magnitude and wave shape. This totally eliminates the "dwell error distortion" and thus the oscillation problems encountered with the open loop Volts/Hz controllers. Applications which greatly benefit from this mode of operation are applications involving high horsepower, high inertia and lightly loaded situations.

The simulated motor speed feedback employed in the RFC provides a much improved ability of the drive to "catch a spinning motor" than the classical open loop Volts/Hz controllers.

Control Mode	Minimum Running Speed Producing Rated Torque	Speed Regulation
V/Hz	2 to 3Hz	2 to 3%
Open Loop Vector	1Hz	1%
Rotor Flux Control	0.8Hz	0.5%
Closed Loop Vector	0Hz	.01%
Servo	0Hz	.01%
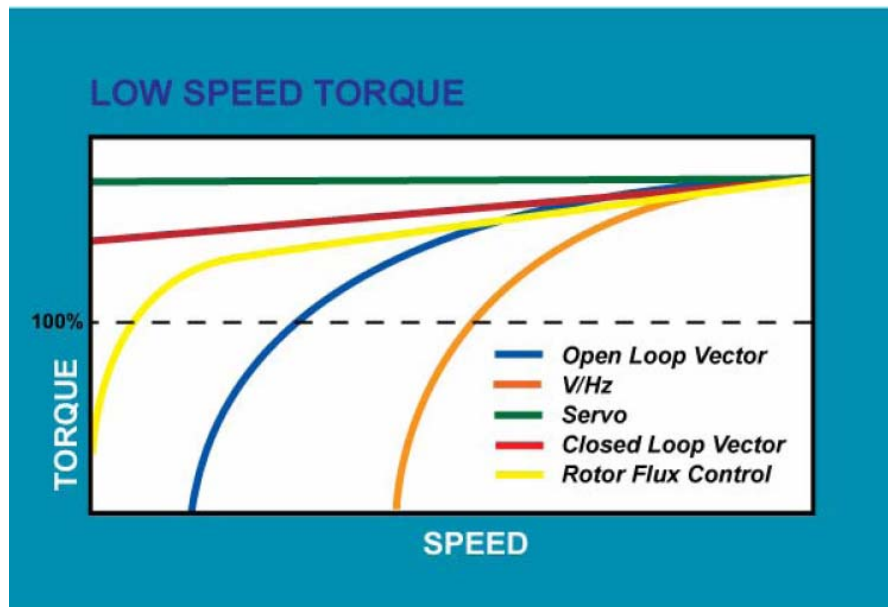
Drive Set UP – UnidriveSP and Commander GP

1. Default the drive to Closed Loop Vector Mode (drive must be in Inh mode- disabled)
   a. Set 00.00 to 1254 for USA Defaults or 1253 for European Defaults
   b. Set 00.48 to CL VECt (RFC for Affinity)

2. Select RFC Mode
   a. Set parameter 3.24 to 1 (no position feedback)

3. Disable Encoder Wire Break (note that this step is not required for Commander GP or Affinity)
   a. Set parameter 3.40 to 0

4. Enter in the Motor Nameplate Data
   a. Motor rated frequency   -- 00.47
   b. Motor rated current   -- 00.46
   c. Motor rated speed   -- 00.45
   d. Motor rated voltage   -- 00.44
   e. Motor rated power factor   -- 00.43 (only if you cannot run the rotating auto tune)

5. Deselect "catch a spinning motor" if not required
   a. Set #6.09 to 0 to deselect

   If "catch a spinning motor" is required, parameter #5.40 should be changed based on the following;

   =1 for motors < 5 Hp
   =2 for motors < 20 Hp
   =3 for motors < 75 Hp
   =4 for motors < 200 Hp

   If the value of Pr **5.40** is too large the motor may accelerate from standstill when the drive is enabled. If the value of this parameter is too small the drive will detect the motor speed as zero even if the motor is spinning.

6. Autotune the drive. It is highly recommended that a rotating auto tune is performed, if it is not possible, a static auto tune must be performed and the motor power factor (from the nameplate) entered manually.

7. Save parameters when programming is complete
   a. set 00.00 to 1000, then press reset

Further tuning

The position estimator used in RFC mode has a filter with a time constant of 4ms which will reduce the possible bandwidth of the speed controller compared with the bandwidth possible when position feedback is used. This means that the speed loop integral gain will need to be lower than the value normally used when a feedback device used. With Unidrive SP software version V01.10.00 onwards, the default of the speed loop I gain has been decreased from 1.00 to 0.10 and the P gain increased from 0.0100 to 0.0300 to help in allowing RFC mode to work well from the default parameter settings. The speed loop gains should be modified to obtain the best possible performance for the application, but it is unlikely that the integral gain can be increased much above 0.50. A filter with a 4ms time constant is always present on the output of the speed estimator, but this filter may be extended by setting Pr 3.42 as follows: 0 = 4ms, 1 = 8ms, 2 = 16ms, 3 = 32ms, 4 = 64ms, 5 = 128ms. The output of the speed estimator can include some ripple, which increases as the drive passes into field weakening and the filter can be used to remove this ripple. This is particularly useful when using standard ramp or spinning start with a low friction high inertia load, and can prevent over voltage trips when the drive has no braking resistor. When operating above rated speed it may be necessary to include further filtering of the current demand (Pr 4.12 set to a value between 1.0 and 5.0ms) to achieve stable operation.

Questions: Ask the author ??
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