

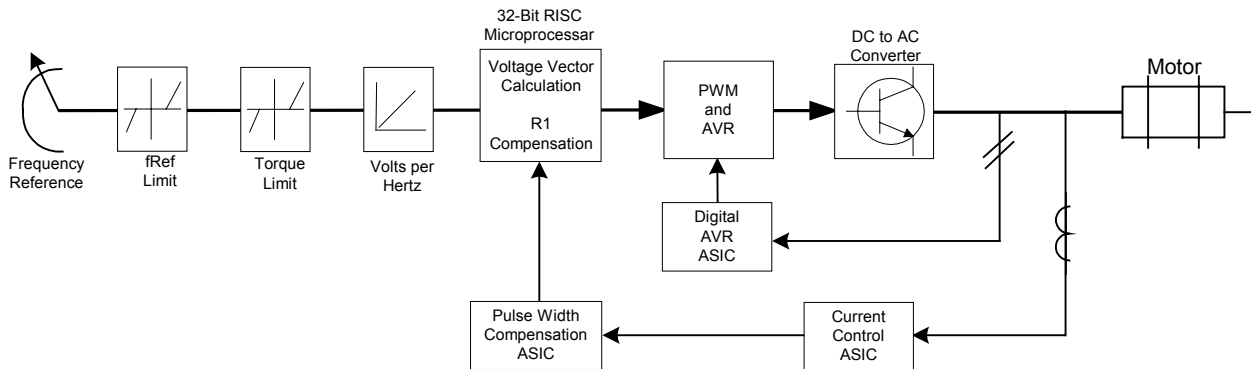
# Dynamic Torque Vector Control And 3 Modes of Auto Tuning

## Flux Vector Control

Flux vector type control has been employed by almost every inverter manufacture for the last several years. The flux vector control concept is to emulate that of the performance of a DC drive and motor package. With the advent of high-speed microprocessors, the AC inverter were able to provide control schemes that were able to accurately separate the magnetizing current and torque producing current of an AC motor. This allowed an AC inverter and motor to perform similar to a DC drive and motor package. In most cases the speed accuracy was greatly improved and the torque control is equal. Do to the many advantages of an AC system verses a DC system, created much demand for the flux vector type of controls to replace previous applications that only DC systems could perform in the past.

In recent years, the application specifications have become more and more stringent on the aspects of tighter speed regulation and improved torque regulation. As well as the desire to have an open loop type control that equals the closed loop flux vector performance, due to maintenance issues and the addition of a speed feedback device. Traditional flux vector controls have lacked the ability to meet these specifications in open loop operation, mainly due to inaccurate motor model mapping, environmental conditions and processor speeds.

Fig.1 Block Diagram of Dynamic Torque Vector Control

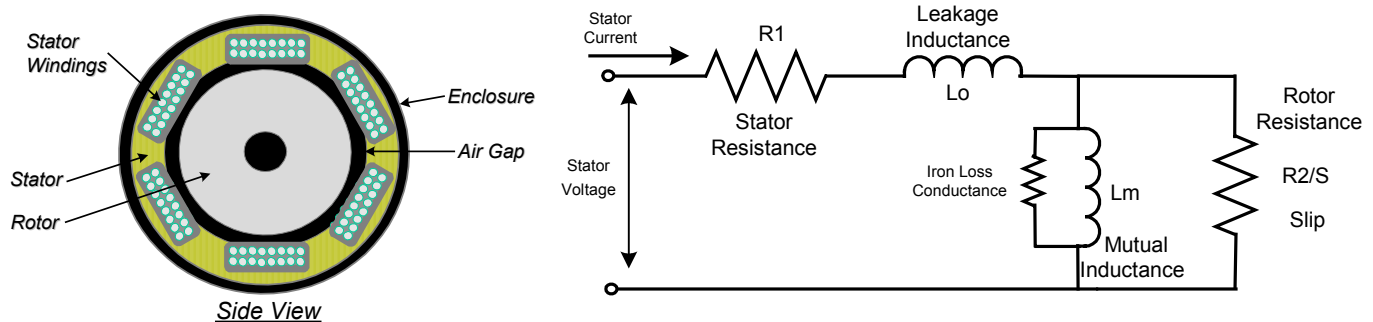


The Safronics 10 series inverters have addressed these issues with the introduction of Dynamic Torque Vector Control. The first issue that was addressed is the processor speed. Safronics is using the latest 32 Bit RISC( Reduced Instruction Set Computer) microprocessor with the capability of executing 30MIPS(million instructions per second). Furthermore, Safronics has developed custom ASIC's (Application Specific Integrated Circuits) with dedicated control functions to speed up execution times up to five times faster than previous control method. The use of custom dedicated ASIC's allowed the main processor quicker evaluation and execution of critical motor information greatly increasing the control accuracy of the ac motor. The three most critical applications that the ASIC's are controlling in the *Dynamic Torque Vector Control* are the pulse width compensation, digital AVR (Automatic Voltage Regulator) and the digital current control. The voltage control pulse width compensation ASIC performs corrections in voltage distortions caused by the non-linear performance of the IGBT's (Insulated Gate Bipolar Transistor). This ASIC executes calculations in 1 microsecond or less, compensating the pulse

width and switching time to create a near perfect sine wave output. The digital AVR ASIC insures the proper output voltage is maintained as instructed regardless of system changes, this ASIC allows execution speeds of several  $10^{th}$  of microsecond. The digital current control ASIC is probably the most important in the Dynamic Torque Control scheme. The current control in an AC inverter requires the highest speed operation, and its performance determines the response of positioning and speed control. Traditionally, this control has been implemented via software, because it requires numerous complex calculations. By implementing this ASIC, the operation cycle speed has increased by a factor of ten. This system has achieved a frequency response of 500Hz or more for the speed control loop.

The second issue addressed was the accurate motor mapping during an auto tune procedure with and with out a load connected. The Safronics 10 series drive have incorporated 3 methods of auto tuning for this purpose. In comparison to other drives in the industry that only supports one auto tune procedure, the auto tune procedure will be discussed in detail later in this paper. The *Dynamic Torque Vector Control* auto tuning method has received two separate patents. The first patent is for the R1 (motor primary resistance) measurement method of an AC motor. Correct measurement of the primary resistance is important in low speed control accuracy. In addition the accuracy of the primary resistance is used for an "On-line" tuning of the motor to compensate for variances in R2, rotor resistance do to changes in temperature of the windings inside the motor. In an AC motor, the component that has the largest variation in value during operation is the rotor resistance, its variation must be accurately compensated by the same method as calculating R1 resistance, since stator resistance varies almost proportionally with rotor resistance. In previous control schemes, compensation for R2 resistance changes were accomplished with thermal sensors from the motor being feedback to the inverter control card. This method is very impractical and cost prohibited.

Fig.2 Motor Construction and Motor Equivalent Circuit



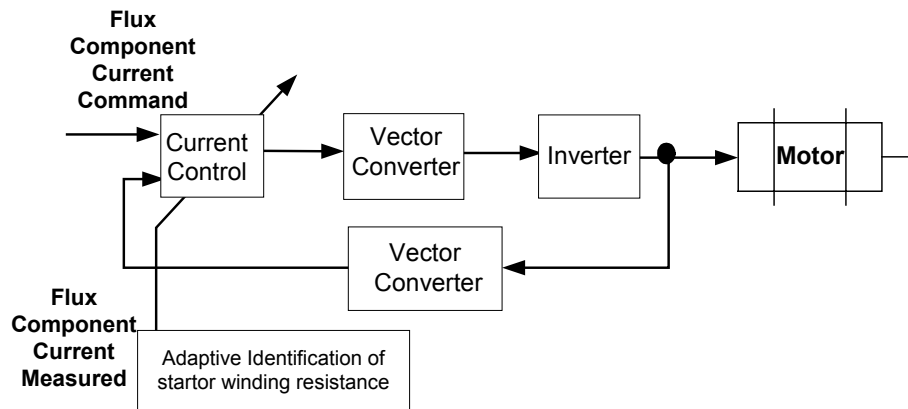
The second patent evolves the measurement of  $L_m$  mutual inductance in the AC motor. This value is one of the most critical measurements in ensuring proper control of the AC motor. The magnetizing current must be properly maintained to ensure proper torque regulation. Once this value has been accurately measured, it must be monitored during operation since the iron loss of this circuit varies. Iron losses consist of eddy current loss and hysteresis losses. Since eddy current losses can be expressed through linear resistance, it is easily addressed. However, the hysteresis loss is a non-linear characteristic depending on the flux level. For this reason, iron loss compensation must be incorporated in the control scheme for accurate control, the patented  $L_m$  tuning addresses this issue.

The *Dynamic Torque Vector Control* scheme of the Safronics 10 series drives truly offer the most advanced and accurate control scheme available today. This control offers wider speed control ranges in both open loop and closed loop configurations, the Safronics 10 series drives offer a speed control range of more than 200:1, more than double the traditional open loop control scheme while providing at a minimum of 180% starting torque at 0.5hz.. In closed loop operation, the Safronics 10 series drives offer a speed control range of more than 1000:1 and greater torque than open loop configuration is able to provide.

## Auto-Tuning

The purpose of the auto-tune, is to determine the motor's design constants or create a motor map(ref to Fig.2). The motor map will comprise of the internal impedance and resistance of the motor and in addition during a dynamic auto-tune the no-load current of the motor will be determined and recorded. The motor map is necessary to input the information into *Dynamic Torque Vector Control* system to maximum the performance of the motor.

Fig.3 Block Diagram of Static Tuning



### Static Auto-Tune

The static auto tune is designed for when the load on the motor can't be removed to perform a dynamic auto-tune or spin the shaft . During the static auto-tune the inverter will determine the primary resistance and base frequency impedance of the motor with no rotation of the shaft and those values will then be programmed into the parameters P07(% R1 Setting)and P08(%X setting).

### Dynamic Auto-tune

The dynamic auto tune is used when the motor is unloaded and able to run the shaft up to half speed without damaging the equipment (uncoupled). The dynamic auto tune provides additional information than a static auto tune, the no load current is now determined during the dynamic auto-tune. The dynamic auto-tune determines the primary resistance, base frequency impedance of the motor and the no load current of the motor, those values will then be recorded into the parameters P06(no-load current),P07(% R1 Setting)and P08(%X setting).

**\* During the Dynamic auto-tune the motor rotates the shaft at half the base speed, beware of the motor rotation as injury may result.**

### Online Auto-Tuning

The induction motor equivalent circuit that shows the largest variation during the operation is rotor resistance. Because the magnitude of slip frequency or V/F controlled induction motor is proportional to the rotor resistance, if the rotor resistance change due to temperature changes during loaded operation, the mechanical speed also varies. In order to maintain constant mechanical speed regardless of the temperature changes in the motor, the online tuning will compensate the output waveform. Online tuning method utilizes the property that stator resistance varies almost proportionally to rotor resistance. The online tuning method enables an improvement in speed drift to as much as 1/3 over a V/F controlled motor.

## Programming

### Auto-Tune Procedure

1. First enter motor constants that cannot be tuned. Set parameters P01 number of motor poles, P02 Motor capacity (HP) and P03 motor rated current (FLA).
2. When tuning the no-load current, beware of motor rotation .
3. Set function P04=1 (No rotation) or 2 (motor rotation). Press FUNC/DATA key to store the value and then press FWD key to start the tuning procedure.
4. Tuning procedure may take about 30 seconds, If P04=2 the motor accelerates up to half of base speed according to acceleration time (F07), is tuned for the no-load current and decelerates according to the deceleration time (F08). The total tuning time varies depending on the acceleration and deceleration times.
5. Press the STOP key and the tuning procedure will end.

**\* During the Dynamic auto-tune the motor rotates the shaft at half the base speed, beware of the motor rotation as injury may result.**

### ***Dynamic Torque Vector Control (open loop)***

After a successful auto tune has been performed, the drive is ready to go into *Dynamic Torque Vector Control* mode. By simply changing function F42 from a value of 0 to 1 that activates the *Dynamic Torque Vector Control* mode (open loop), the inverter is then able to maximum the performance of the motor. The Dynamic Torque Vector mode will supply up to 200% starting torque at 0.5Hz, speed regulation of +/- 0.04% and a speed range of more than 200:1, without the use of an encoder or feedback device.

#### Programming

F42 =1 Torque Vector mode

F42 = 0 Volts per hertz mode(factory default)

### ***Dynamic Torque Vector Control (closed Loop)***

To operate in *Dynamic Torque Vector Control* mode(closed loop) options card and encoder are required. The option card transmits pulses for the encoder, that is mounted on the motor to the inverter has a means of feedback or closing the loop (closed loop). Once in *Dynamic Torque Vector Control* mode the inverter is capable of providing torque at zero speed with a speed regulation of +/- .01% and a speed range of more than 1000:1.

#### Programming

O01 = 01 Closed loop operation

O03 = 1024 Number of pulse per revolutions(PPR)