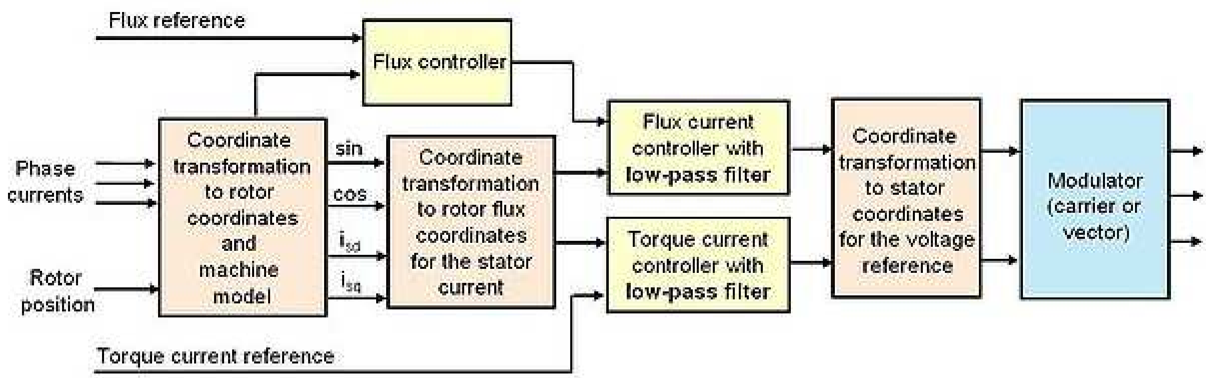
Vector control (motor)

Vector control (also called Field Oriented Control, FOC) is one method used in variable frequency drives to control the torque (and thus finally the speed) of three-phase AC electric motors by controlling the current fed to the machine.

The stator phase currents are measured and converted into a corresponding complex (space) vector. This current vector is then transformed to a coordinate system rotating with the rotor of the machine. For this the rotor position has to be known. Thus at least speed measurement is required, the position can then be obtained by integrating the speed. Then the rotor flux linkage vector is estimated by multiplying the stator current vector with magnetizing inductance Lm and low-pass filtering the result with the rotor no-load time constant Lr/Rr, that is the ratio of the rotor inductance to rotor resistance.



Using this rotor flux linkage vector the stator current vector is further transformed into a coordinate system where the real x-axis is aligned with the rotor flux linkage vector. Now the real x-axis component of the stator current vector in this rotor flux oriented coordinate system can be used to control the rotor flux linkage and the imaginary y-axis component can be used to control the motor torque.

Typically PI-controllers are used to control these currents to their reference values. However, bang-bang type current control, that gives better dynamics, is also possible. With PI-controllers the outputs of the controllers are the x-y components of the voltage reference vector for the stator. Usually due to the cross coupling between the x- and y-axes a decoupling term is further added to the controller output to improve control performance when big and rapid changes in speed, current and flux linkage occur.

Usually the PI-controller also needs low-pass filtering of either the input or output of the controller to prevent the current ripple due to transistor switching from being amplified excessively and unstabilizing the control. Unfortunately, the filtering also limits the dynamics of the control system. Thus quite high switching frequency (typically more than 10 kHz) is required to allow only minimum filtering for high performance drives such as servo drives. Next the voltage references are first transformed to the stationary coordinate system (usually through rotor d-q coordinates) and then fed into a modulator that using one of the many Pulse Width Modulation (PWM) algorithms defines the required pulse widths of the stator phase voltages and controls the transistors (usually IGBTs) of the inverter according to these.

This control method implies the following properties of the control:

- Speed or position measurement or some sort of estimation is needed.

- Torque and flux can be changed reasonably fast, in less than 5-10 milliseconds, by changing the references.

- The step response has some overshoot if PI control is used.

- The switching frequency of the transistors is usually constant and set by the modulator.

- The accuracy of the torque depends on the accuracy of the motor parameters used in the control. Thus large errors due to for example rotor temperature changes often are encountered.

- Reasonable processor performance is required, typically the control algorithm has to be calculated at least every millisecond.

Although the vector control algorithm is more complicated than the Direct Torque Control (DTC), the algorithm is not needed to be calculated as frequently as the DTC algorithm. Also the current sensors need not be the best in the market. Thus the cost of the processor and other control hardware is lower making it suitable for applications where the ultimate performance of DTC is not required.