Technical Note

VFD Motor Control Modes

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History

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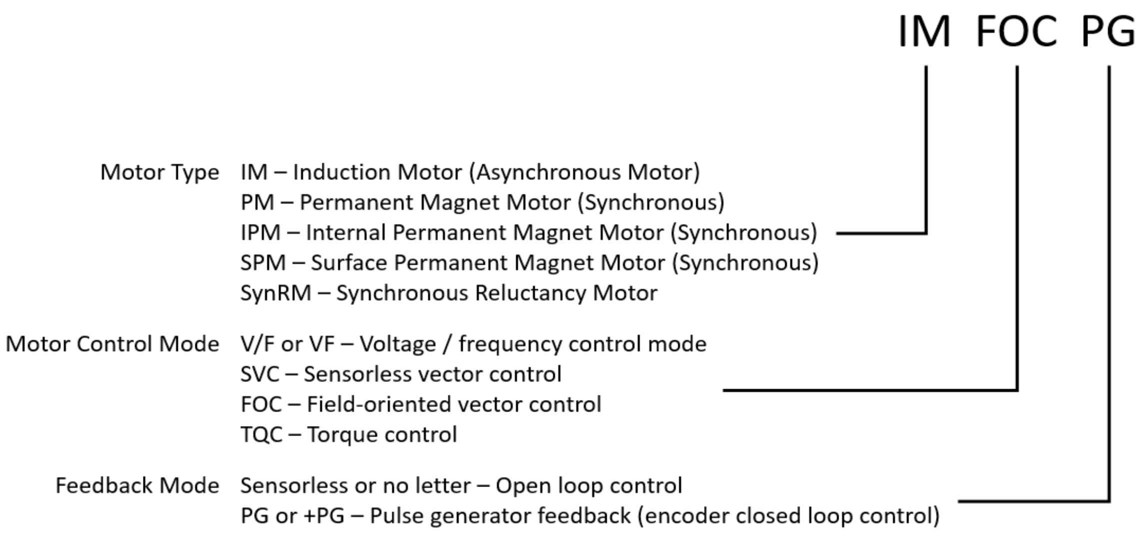
1 Introduction

This technical note clarifies the meaning of abbreviations like IM VF + PG, IPM FOC, PM TQC and the likes. It also explains how the related modes work and when to use them.

Be aware that this document addresses qualified persons, and it cannot replace profound technical education and training.

2 Motor Control Mode Code



Not all mode combinations are possible. The availability of modes depends on the drive model, and is prone to change. Please check with your Delta contact or in the corresponding user manual.

2.1 Motor Type

IM induction motors are the most common motor types. They are easy to make and source, are robust and come at reasonable prices. Until recently, users regarded their efficiency as satisfying. Newer regulations and legislation require higher efficiency ratings. Induction motors are running into the physical limits, when it comes to further improvements in that regard.
Another disadvantage is that they suffer from slip. That means, their rotor speed depends on the load and is not synchronous to the speed of the electrical field.

PM permanent magnet motors are the classical synchronous machines. They provide higher efficiency than induction motors, but the rare-earth magnets in them make them more expensive. They need advanced control algorithms, which requires more effort during commissioning.
EC electronically commutated motors, also known as brushless DC motors behave like PM motors. The same control modes are suitable for them.

IPM internal permanent magnet motors have their magnets inside of the rotor. Such a design is more difficult to manufacture and increases the price of this motor type.

SPM surface mounted permanent magnet motors come with magnets on the outside of the rotor, which makes them easier and cheaper to manufacture. The manufacturing precision of magnets is inferior to steel. Hence, the air gap between stator and rotor needs to be bigger than in IPM motors. As a result, SPM motors have slightly lower efficiency than IPM motors.

SynRM synchronous reluctancy motors are currently the champions when it comes to efficiency. Their manufacturing and material cost are low, because they do not need magnets or copper windings on the rotor. The drawback is that this motor type has a very small overload capacity, which only makes it suitable for applications with little overload demand, e.g. centrifugal pumps.
SynRM motors need advanced control algorithms, especially for starting them up. Therefore, only few drives can control SynRM motors at the time of writing this note.

2.2 Motor Control Mode

V/f voltage/frequency control mode is the default control mode for most VFDs.
According to the V/f parameters, the drive creates a table that defines a frequency value for each voltage value. The drive produces a corresponding output voltage and frequency without regard for the actual rotor speed. Induction motors will turn slower than the drive's output frequency due to slip, which is a result of their operating principle.
V/f is the mode of choice for applications that do not require precise speed and torque control, e.g. centrifugal pumps or fans.

SVC sensorless vector control mode does not require a V/f table. It starts on the assumption of a linear curve between the highest and the lowest frequencies and voltages. According to the motor current, the controller estimates the actual rotor speed. If the speed does not coincide with the speed command, the drive modifies the output voltage until the rotor reaches the desired speed.
This mode activates the automatic slip compensation. For induction motors that means, the drive output frequency may be higher than the maximum frequency setting, because the maximum frequency refers to the rotor frequency, not to the drive's output frequency.
SVC mode suits applications that need slightly more speed and torque precision at low speed, e.g. conveyors or positive displacement pumps.

FOC field-oriented control mode provides servo-like behaviour. Clarke-Park transforms allow for precise calculation of the actual motor state and of the necessary voltage and frequency commands to control the motor's behaviour.
The feedback of this mode is based on current measurements, which makes it more precise than V/f and SVC modes, especially at very low motor speed.
FOC modes can solve applications which need high starting torque at very low speed, like stone crushers or hoist lifts. They are also well suited for precise speed, torque and position control.

TQC torque control allows to operate the drive as torque controller instead of speed controller, e.g. for tension control applications. It is based on FOC mode.

2.3 Feedback Mode

Modes with PG encoder feedback operate on the same principles as the modes without encoder.. The difference is that for modes without PG the feedback parameter is the measured drive output frequency. With PG, the feedback parameter is the measured encoder speed. Figure 2.3.1 shows the difference by taking V/f and V/f + PG modes as example.

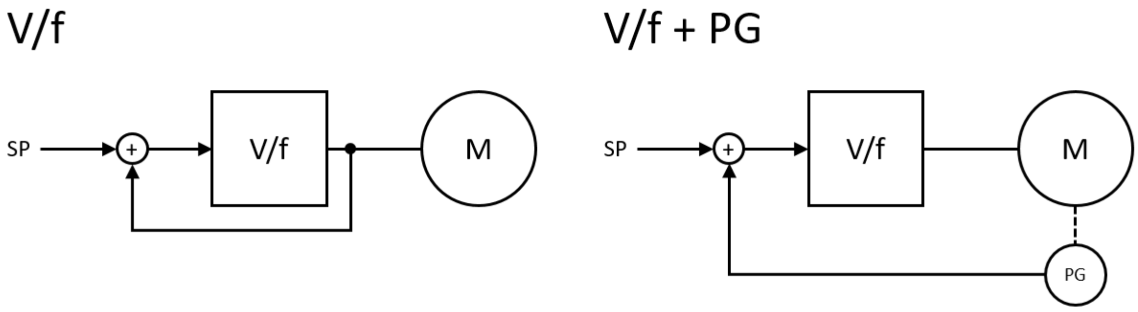


Figure 2.3.1 Simplified V/f Block Diagrams

In PM FOC modes, the encoder also determines the rotor angle to optimise motor control.

3 Motor Control Mode Properties

Table 3.1 Motor Control Mode Performance

Mode	Speed Range	Starting Torque
IM VF IM VF + PG IM SVC	1:50	150% @ 3 Hz
PM SVC	1:20	100% @ $\frac{Parameter\ 01-01\ (Rated\ Motor\ Frequency)}{20}$
IM FOC Sensorless	1:100	200% @ 0.5 Hz
IPM FOC Sensorless	1:100	150% @ 0 Hz
PM FOC Sensorless	1:50	100% @ $\frac{Parameter\ 01-01\ (Rated\ Motor\ Frequency)}{50}$
IM FOC + PG	1:100	200% @ 0 Hz
PM FOC + PG	1:1000	200% @ 0 Hz
SynRM Sensorless	1:20	100% @ $\frac{Parameter\ 01-01\ (Rated\ Motor\ Frequency)}{20}$

The above values depend on correct tuning as well as on external circumstances, and may not be achievable all the time.

The speed range relates to parameter 01-00 (maximum speed). Using V/f mode as example, a maximum speed setting of 100 Hz would lead to a useable 1:50 speed range from 2 Hz to 100 Hz.
That does not mean, the motor will not run at all below 2 Hz, but the control quality will not be as good as between 2 Hz and 100 Hz.
In practical applications, the requirements at such low speed will often be less rigorous, so that the control quality is oftentimes acceptable.

The same goes for the starting torque. The motor will be able to operate below 3 Hz, but only if the torque demand is low, e.g. for pumps, fans or conveyors. The starting torque refers to the motor’s nominal torque as 100%.

For applications that require high starting torque at very low speed, make sure to choose the adequate motor control mode.