Industrial/Appliance PMSM Drive

Sensorless PMSM field-oriented control for compressors, fans, pumps and similar drives

**Introduction**

Sensorless permanent magnet synchronous motor (PMSM) field-oriented control (FOC) for industrial or appliance drives is gaining popularity as a cost-effective, energy-efficient controller solution. This article provides information on the sensorless PMSM FOC for compressors, fans, pumps and similar drives.

**Typical Requirements**

Industrial or appliance drives such as compressors, fans and pumps are usually variable power with a mid-speed operation range.

Control requirements include:

- Sensorless FOC of a PMS motor. To achieve this, a powerful DSC must be chosen.
- Speed 200 to 10,000 RPM mechanical. The sensorless algorithm must estimate position and speed within this speed range.
- Startup and alignment torque depends on the drive. The compressors have high start-up torque while the fans have low.
- PWM frequency of 5 to 10 kHz. This is a compromise among switching losses, audible noise and enough samples for the sensorless control, where the ADC is synchronized to the PWM.

**Application Concept**

**FOC**

The PMS motor rotates when its three phases are supplied by sinusoidal current. The phase of each sine must be aligned to the rotor position to create torque. The torque is proportional to the supplied current. It is time consuming to control three sinusoidal wave forms. Therefore it is essential to decompose the three components into two components aligned to the rotor position. Then, the two components are used to control the system: one that controls the field and the other, the torque.

Finally, there are PI controllers to control these two currents. The desired torque current value is provided by the output of the speed PI controller. The magnetization current is kept at zero until the strength of the field is reduced. This moment occurs when the speed is high and the induced BEMF is at the level of the DC bus voltage; it is not possible to reach higher speeds. By reducing the strength of the field, the lower level of BEMF is induced. In this case, the DC bus voltage has a reserve to be applied on the motor and the current can then be increased in the motor. A higher speed is then reached.

Freescale has developed this method of field weakening.

**Sensorless Driving**

This application requires position and speed information. The use of a position sensor is costly, so it cannot be used. Therefore, it is necessary to get the position and speed without the need of additional physical position sensors.

To reach the speed and position, it is necessary to know the motor parameters well to calculate its model observer. The parameters are programmed into the algorithm called the BEMF observer. This observer’s function is to calculate the position of the BEMF, which is needed to drive the motor. The position is then passed
through the tracking observer to be filtered, and as a side product the actual speed is filtered. Its inputs for current, applied voltages and speed are then measured.

This solution requires a powerful controller from the Freescale 56800E/Ex family of DSCs.

**Implementation**

Freescale offers a selection of DSCs for this important task. The following is a list of what is mandatory for such an application:

- **PWM**: Should offer center-aligned mode, complementary switching capability with the deadtime insertion, three-phase oriented and synchronization with the ADC.
- **ADC**: Simultaneously measures two currents, with two channels working in parallel.
- **SCI**: Necessary for the communication with FreeMASTER to allow application debugging.
- **Interrupt controller**: Must be priority controlled to avoid disintegrity of the control technique. The interrupt latency should be short.
- **Core**: Must have great computation potential in terms of mathematical operation.

**Performance**

The application uses two main loops: current and speed. The current loop is critical and is calculated on the PWM frequency of 10 kHz. The loop has several tasks:

- Reading of measured currents and voltage, and reconstruction of the current from two values into three
- BEMF + tracking observer
- Clarke and Park transformation
- D and Q current controllers and their limitation depending on the DC bus voltage
- DC bus ripple compensation
- Space vector modulation
- PWM update
- ADC configuration for the next step

The duration of the current loop has been measured as 14 μs (measured on a 100 MHz DSC). The speed loop runs at the period of 1 to 5 ms.

Tasks include:

- Speed ramp calculation
- Speed PI controller calculation
- Field weakening algorithm

The speed loop duration has been measured as 1.8 μs. The code occupies 3165 words of ROM and 279 words of RAM.

**Freescale Enablement**

- Application based on FSLES
gesus.com/motorcontrol
- Embedded software and motor control libraries
gesus.com/fslesl
- FreeMASTER visualization tool
gesus.com/freeMASTER
- Application support from Freescale motor control experts
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