Industrial Drives
Simple ACIM V/Hz Drives

Introduction
This article describes the basic control method for an AC induction motor (ACIM). The method principle, hardware and software implementation will be explained, and solutions will be recommended and described.

ACIM V/Hz Control
Open loop voltage/frequency (V/F) control (scalar control) is one of the most frequently used, simplest control methods. This method doesn’t require high computing power and there is no feedback, which means that the rotor speed accuracy remains low and an expensive speed sensor is not required. Scalar control is typically used for drives where changing of speeds is required and low accuracy speed regulation and low dynamic performance are acceptable. This makes ACIMs with V/Hz control convenient for low-cost drives like fans, ventilators, pumps, compressors and as a driver of other appliances. These drives also enjoy the benefit of requiring little maintenance.

V/Hz Principle
The volt per hertz (V/Hz) control method is one of the most popular scalar methods, and controls the magnitude and frequency of variables such as frequency, voltage or current. This method principle is based on motor speed being proportional to supply voltage frequency, enabling motor speeds to be easily changed. The applied stator voltage is calculated directly from the applied frequency in order to maintain a constant air gap flux within the machine.

The stator supply voltage must also vary according to frequency, as the result would be an overcurrent in the motor winding. The control algorithm maintains a constant magnetizing current (flux) in the motor by varying the stator voltage with frequency. Figure 1 shows the relation between stator voltage and frequency.

The most common high efficiency technique for maintaining an average voltage level is via pulse width modulation (PWM). In this method, voltage pulses are not an issue, as motor winding includes inductance which ensures a smooth current in the stator.

For sine stator current generation, the duty cycle of the stator voltage pulses fluctuate in relation to the sinusoidal reference signal.

Below the base point, the motor operates at optimum excitation, called constant torque operation, due to the constant V/F ratio. Above this point, the motor operates under-excited, called constant power operation, due to the limit of the rated voltage.

Block Control Scheme
Figure 2 shows the V/Hz control structure, which can be divided into hardware and software. The hardware consists of a frequency converter, sensors and driver, while the software is comprised of a control algorithm.

Hardware
The motor is supplied by the adjustable frequency generated from the frequency converter with voltage DC bus. The frequency converter consists of an input diode rectifier, DC bus capacitor and output voltage three-phase inverter.
The inverter is built from three half-bridge units (see figure 3) where the top and bottom switch are controlled complementarily. This means that once the first switch is turned on, the second must be turned off, or vice versa. During state change, both switches are turned off, resulting in dead time.

The most popular devices for motor control applications are power MOSFETs and IGBTs.

Modulation Techniques

There are two pulse generation methods for each complementary pair. An easier method uses a comparison of an isosceles triangle carrier wave with a sine-modulating wave, as shown in figure 4.

The more complicated, but more effective method of space vector modulation uses six active vectors and two zero vectors. Each active vector corresponds to three transistors from the top and bottom area. The zero vectors activate either all top or all bottom-switching elements. The space between active vectors relates to a combination of the nearest active vector and arbitrary zero vector.

Software

The application measures the DC bus voltage, current and temperature. The overcurrent and overvoltage faults are checked to avoid drive failure. The DC bus voltage is also used for the ripple elimination.

The speed command is processed using the ramp. The corresponding voltage is calculated using the V/Hz ramp and the DC bus ripple elimination block then eliminates the influence of the DC bus voltage ripple according to the generated phase voltage amplitude. The PWM generation process calculates a three-phase voltage system from the required amplitude and frequency.
Finally, the three-phase PWM inverter pulses are generated.

**Recommended Devices**

For the solution described, Freescale S08MP16 or Kinetis series MCUs are recommended depending on the core required.

The S08MP16 is an 8-bit device with frequencies up to 50 MHz and an HCS08 core. The Kinetis K series offers a more powerful 32-bit ARM® Cortex™-M4 core with frequencies up to 150 MHz. The K series also integrates up to 1 MB of flash and 128 KB SRAM versus the 16 KB flash and 1 KB RAM memory of the S08MP16. Kinetis K40 MCUs also offer a 144 LQFP or MAPBGA package in comparison with the maximum 48-pin LQFP package of the S08MP16.

Both devices include the FlexTimer module for PWM generation and PDB module for triggering. The S08MP16 has only one 12-bit ADC against two ADCs with up to 16-bit resolution offered with Kinetis K40 MCUs.

Selecting the right device depends upon the requirements of your application. If your application is performing multiple processes on a single device, the more powerful, higher performance Kinetis MCUs offer a simple solution. For a more cost-effective solution, the S08MP16 is ideal.

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