INTELLIGENT CONTROL OF MOTORS

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Summary

Today, development in computer technology is advancing rapidly. It is now possible to design the motors to operate in a highly dynamic and controlled fashion. The term “intelligent control of motors” is applied to a computer-based method that can make the actuators or motors become more intelligent, particularly in their motion, measurement,

and control. This is particularly important now as manufacturers and consumers require more and more intelligent machines and better optimization of their performance in terms of human–machine interface, production, automation, and so on. The typical requirements of intelligent motion control are high-speed computers, high dynamic performance motors, and good sensors. Extensive research on mechatronic actuators has been carried out in order to create a new generation of intelligent motors. New concepts of the techniques required for good modeling of the device and system, good control algorithms, and switched reluctance motors are good candidates for these applications. Advanced control algorithms including neural and fuzzy control are also being used.

1. Introduction

The history of the control of electric machines goes back to the early twentieth century. Power electronics began to grow in the early 1970s, and this growth provided a major step forward in motion control. During that period, the dynamic performance of direct current (DC) machines was superior to that of alternating current (AC) machines. The switching speed of transistors increased with the evolution of variable-speed drives in AC machines. Scalar control of the AC machines, such as constant V/F control, was introduced. At that time the machines were nonlinear and their parameters varied considerably, which created problems such as poor stability and poor dynamic performance. In the late 1970s, vector or field-oriented control of AC machines was introduced. It became very popular in the 1980s and achieved a high degree of maturity. This control method enabled AC motors to be controlled in the same way as DC motors. Both the torque and the field could be regulated separately, and this significantly increased the dynamic performance. The latest development in motor drives is direct torque control, which has been found to have various applications in actuation systems and traction drives. The intelligent control of AC motors has also begun to develop, based on two methods. The rapid development of microprocessors, digital signal processors, and artificial intelligent techniques, and the advancement in control and estimation techniques, have also enabled motors to be controlled in a much simpler way than in the past.

This article will review various control methods for a number of motors. The methods include vector control, direct torque control, adaptive control, sliding mode control, and sensor and sensorless controls.

2. Control Methods for Motors

2.1. High Dynamic Performance

A good motor control system is able to response instantly to the command signal, with a very high accuracy. The system can also perform when there are changes in operation and environment, or variations in the parameters of machines. Four basic control methods for AC machines will be discussed here. They are vector control, direct torque control, adaptive control, and intelligent control.

2.2. DC Drives

The conventional separately excited DC motor is one of the most popular motors. This is because the field and the armature current (which govern the speed and the torque) can be controlled separately. The dynamic response of the motor is excellent and the cost is low, thus it has a very large market. However, this situation is likely to change because other motor drives are now catching up, and they will have a similar performance and a lower cost.

The differences between the DC drive and AC drive are quite clear. The classical DC motor requires a commutator and brush, and field winding or a permanent magnet, whereas other motors are operated directly on the DC, and power electronics are needed to control the switching pattern to the motors. Switched reluctance motors (SRMs) and permanent magnet DC brushless motors (PMDCBM) are examples. SRMs have a low rotor inertia, which implies a better dynamic response, and a simpler structure and cheaper cost.

2.3. Modulation

2.3.1. DC Drives

Pulse-width modulation (PWM) is used to control motors. Its function is to vary the voltage applied to the motor. As the switching frequency is very high, the average voltage of the motor is equal to the average of the PWM signal. For the control of a DC motor, the armature voltage is regulated by the PWM. As is shown in Figure 1, a chopper is used to control the mark–space ratio D of the armature voltage, with a source voltage of V_{in}. Therefore, the average armature voltage is equal to DV_{in}. The motor speed ω can be shown to be:

$$\omega = \frac{DV_{in}}{k\phi} - \frac{R_a T}{(k\phi)^2} \tag{1}$$

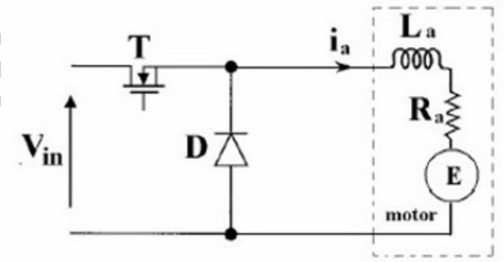

Figure 1. A simple control circuit for a DC motor

It can be seen that the motor speed is inversely proportional to the torque T and proportional to D. The above control method is only for unidirection power flow, hence no regenerative braking and plugging can be applied to the motor. An H-bridge circuit is more often used in DC motors for four-quadrant control as shown in Figure 2. The control of the DC motor is in fact very simple, because the armature current and field current can be regulated separately, therefore the torque and field can be controlled easily.

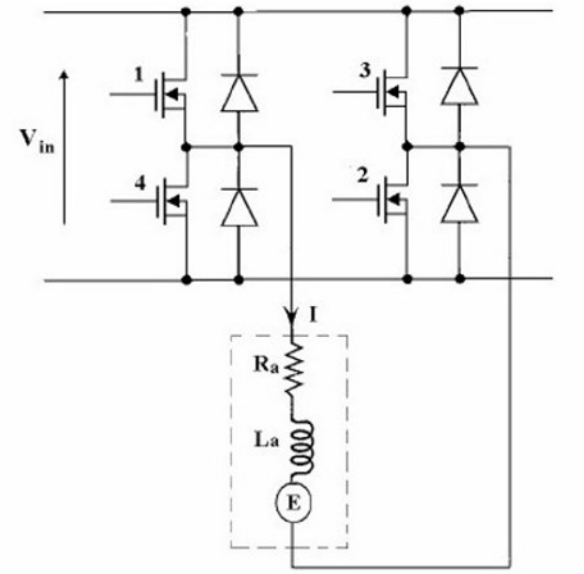

Figure 2. Four-quadrant control of a DC motor

2.3.2. Basic Concept of Pulse-Width Modulation for AC Drives

The induction motor is a popular motor drive because a permanent magnet is not needed. For AC motors such as the induction motor, a sinusoidal PWM is used. A large number of pulses per cycle are used in order to synthesize a voltage wave that has a dominant fundamental sine-wave component and small harmonic components. The relative widths of the pulses are made approximately proportional to the desired sine wave to the motor. The pulse width for the rising half and falling half of a pulse is:

$$\delta_{1k} = \delta_o(1 + M\sin(\omega t - \delta_0))$$
$$\delta_{2k} = \delta_o(1 + M\sin(\omega t + \delta_0))$$

M is the modulation index, which governs the amplitude of the output voltage, δ_0 is a quarter of a switching period and ω is the output frequency. At any time t, the corresponding pulse width can be calculated by the above equations. Hence, the applied voltage and the frequency of the motor can be established by the PWM. This forms the basic concept behind the variable speed drives of AC machines. The modulation index is related to the modulating voltage and the input voltage of the inverter for the motor by the equation below:

$$M = \frac{\textit{peak value of the fundamental sine wave}}{\textit{peak value of the carrier wave}} = \frac{V_m}{V_{in}/2}$$

V_m is the peak value of the modulating voltage, that is, the output phase voltage. From the two equations above, it can be concluded that a motor is controlled to regulate the modulation index and output frequency.

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Biographical Sketch

K.W.E.Cheng graduated from the University of Bath, UK, and obtained his Ph.D. in 1990. He became a project leader, then principal engineer, for Lucas Aerospace Ltd., UK. He joined the Hong Kong Polytechnic University in 1997 and is now an Associate Professor. His research interest is in all aspects of power electronics and drives. He has published more than 100 papers in these areas. Dr. Cheng is a Chartered Engineer, and a member of IEE and IEEE.