7 A.C. Motors

7.1 GENERAL PRINCIPLES

In order to produce rotary motion in an electrical machine, the current in the rotating part must always react with the magnetic field so that it produces a force which acts in one direction only. In a d.c. machine this action is brought about using a static magnetic field, whereas in a.c. machines the magnetic field rotates at high speed (see also section 7.2).

7.2 PRODUCTION OF A ROTATING MAGNETIC FIELD

The stator of a simplified a.c. induction motor is shown in figure 7.1a. This machine has three concentrated windings displaced 120° from one another; in a practical machine the windings are uniformly distributed in slots around the inner surface of the cylindrical stator.

When a balanced three-phase supply is connected to the three windings, the waveforms of the currents in the windings are as shown in figure 7.1b. In the following we consider how the total m.m.f., $F_T$, produced by the windings changes as the current changes. The following convention is adopted in figure 7.1; when the current flows in the direction shown on each winding in figure 7.1a, the direction of the m.m.f. developed by each coil is radially outwards from the centre of the stator; reversing the direction of the current reverses the direction of the m.m.f.

M.M.F. at $\theta = 0°$

When $\theta = 0°$ in figure 7.1b, $I_R = 0$ and the corresponding value of the m.m.f. is zero. The value of $I_Y$ is 0.866 of its maximum value, but is in its negative half-cycle; thus m.m.f. $F_Y$ is 0.866 of its maximum and acts radially inwards. This is illustrated in figure 7.1c. The value of $I_B$ is +0.866 of its maximum value and the m.m.f. $F_Y$ acts radially outwards. The total m.m.f. $F_T$ is the phasor sum of the individual m.m.f.s, illustrated in figure 7.1c. As a result, the simple three-winding system shown produces a two-pole magnetic field.
value, \( I_Y = -0.866 \) of its maximum value, and \( I_B = 0 \). The corresponding m.m.f.s are illustrated in figure 7.1d, and the net result is that the m.m.f. phasor \( F_T \) is seen to have rotated through 60° in a clockwise direction.

**M.M.F. at \( \theta = 120^\circ \) and 180°**

Applying the appropriate values of current given in figure 7.1b for these angles to the m.m.f. diagrams in figures 7.1e and f, respectively, shows that the m.m.f. phasor continues to rotate in a clockwise direction with a 1:1 ratio between the value of \( \theta \) on the current waveform and the angle of rotation of the m.m.f. phasor.

From the above, the reader will observe that the m.m.f. phasor, \( F_T \), has a constant value which rotates at a constant speed which is related to the supply frequency; one cycle of \( F_T \) taking place in one cycle of the supply waveform.

### 7.3 RELATIONSHIP BETWEEN SPEED, FREQUENCY AND NUMBER OF POLES

From the above, in the case of a two-pole (or one pole-pair) machine, the flux rotates through one complete revolution in one cycle of the supply. If the stator is wound with \( p \) pairs of poles, the flux will rotate through \( 1/p \)th of a revolution in one cycle of the supply waveform, that is, \( f/p \) revolutions per second. Hence the speed of revolution, \( n_s \), of the rotating field is

\[
  n_s = f/p \text{ rev/s}
\]

or

\[
  f = n_s p \text{ Hz}
\]

The speed of rotation, \( n_s \text{ rev/s} \) (or \( \omega_s \text{ if in rad/s} \)), is known as the *synchronous speed* of the rotating field. Hence at a supply frequency of 50 Hz the synchronous speed associated with a four-pole (or two pole-pair) system is \( n_s = f/p = 50/2 = 25 \text{ rev/s} \) or 1500 rev/min.