9

Single-phase Motors

TOPICS DISCUSSED

- Revolving field theory
- Single-phase split-phase induction motors
- Torque-speed characteristic and applications
- Shaded pole induction motor
- AC series motor
- Universal motor
- Single-phase synchronous motors
- Stepper motors

9.1 INTRODUCTION TO SINGLE-PHASE INDUCTION MOTORS

Single-phase induction motors are widely used in electrical appliances and gadgets like ceiling fans, exhaust fans, refrigerators, washing machines, etc. They require only single-phase supply to the stator. The rotor is squirrel-cage type and does not require any supply from a separate source.

9.2 CONSTRUCTIONAL DETAILS

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not develop starting torque unless some mechanism for starting the motor is provided. An auxiliary winding is provided in the stator for developing starting torque. Let us now examine as to why a single-phase supply given to a single-phase stator winding of the motor does not lead to the development of any torque. Fig. 9.1 shows a single-phase induction motor in cross-sectional view and a single-phase supply connected to its stator terminals.

The stator winding shown has been made with only three coils. In actual practice more coils will be used. The rotor has a squirrel cage winding. When supply from a single-phase source is applied, current will flow through the stator winding for the instantaneous polarity of voltage shown. The North and South poles formed in the stator along with the magnetic field axis have been shown. Since the supply voltage is varying sinusoidally the magnitude and direction of the flux produced will change. EMF will be induced in the rotor winding. The rotor winding being a closed winding current will flow through it. The direction of flux produced will be such that the rotor flux will oppose the stator flux (according to Lenz's law). Thus, the two magnetic fields, i.e., one produced by the stator current and the other produced by the rotor-induced current will be aligned to each other. The axis of the two magnetic fields will be along the horizontal axis. See Fig. 9.1 (a). Since there is no angle of non-alignment between the two magnetic fields, no torque will be developed and hence there will be no rotation of the rotor. The single-phase induction motor as such will not be self-starting.

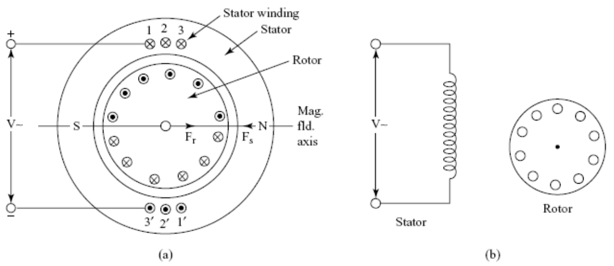

Figure 9.1 Single-phase induction motor without any starting winding

It has however been observed that if the rotor is given some initial torque in any direction it picks up speed in that direction and continues to rotate. Thus, a single-phase induction motor without any starting mechanism will not develop any torque at starting but will pick up speed if it is given an initial rotation.

To explain this, two theories were developed. These theories are

1. double revolving field theory;
2. cross-field theory.

We will explain one of these theories to show why a single-phase induction motor does not develop any starting torque but requires an initial torque to be provided for it to continue to rotate.

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stant magnitude (half the magnitude of the alternating field) rotating in opposite directions at synchronous speed.

Thus, an alternating field can be seen as a resultant of two revolving magnetic fields which will have an effect on the rotor which is placed inside that alternating field. The component rotating fields will develop torque on the rotor due to the induction effect and the rotor will rotate on the basis of the resultant torque developed due to these two revolving fields.

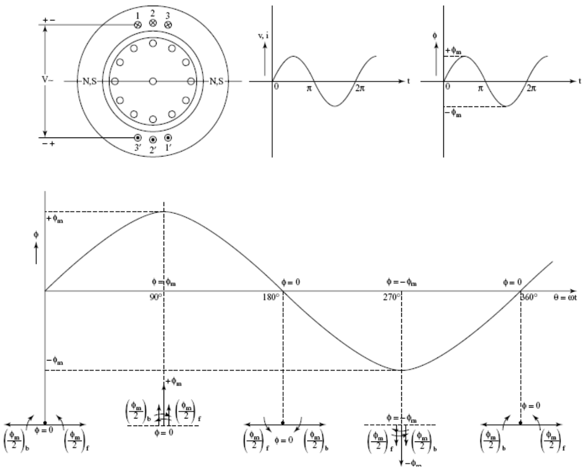

Figure 9.2 Double revolving fields represented through vectors at different instants of time

Thus, a single-phase induction motor having a single-phase supply on its stator winding can be visualized as two three-phase induction motors trying to rotate the rotor in opposite directions. The rotor, however, rotates in one direction due to the effect of resultant of the two torques developed in opposite directions.

The double or two revolving field theory is explained with the help of vector representations as in Fig. 9.2. The alternating magnetic field is represented by a vector, ϕ, which varies from its positive maximum value to negative maximum value, in every half cycle of current flow through the stator winding. This maximum of ϕ as ϕ_m has been shown by two vectors $\frac{\phi_m}{2}$ and $\frac{\phi_m}{2}$; the sum of these two vectors will always be equal to ϕ_m. As the flux produced varies sinusoidally, it will be observed that this magnetic flux at every instant of time is the vector sum of two rotating magnetic fields.

In Fig. 9.2 is shown the stator winding connected to a single-phase supply voltage V. The current flown and the flux produced have been shown. As the current changes its polarity every half cycle, the

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270°, and 360°. We have considered ϕ_m as the sum of two vectors $\frac{\phi_m}{2}$ and $\frac{\phi_m}{2}$; , the sum of which at every instant of time will be equal to ϕ_m. Two component vectors have been represented in the figure as $\left(\frac{\phi_m}{2}\right)_f$ and $\left(\frac{\phi_m}{2}\right)_b$. $\left(\frac{\phi_m}{2}\right)_f$ represents *forward field* rotating in anticlockwise direction and $\left(\frac{\phi_m}{2}\right)_f$ and $\left(\frac{\phi_m}{2}\right)_b$ represents *backward field* rotating in the clockwise direction at the same speed. The speed of rotation of the two fields is the same and is synchronous with the alternating magnetic field. At θ = 0, the two fields are shown opposite to each other so that the resultant flux ϕ = 0. At θ = 90°, the two flux vectors have rotated by 90° in opposite directions and the resultant flux is +ϕ_m. At θ = 180°, the two component flux vectors have rotated by another 90° and the resultant flux ϕ = 0. At θ = 270°, the vectors have rotated in opposite directions by another 90° and the sum of the two vectors is – ϕ_m. At θ = 360°, the two vectors have again rotated by another 90° and their sum is now equal to zero. Thus, for one complete cycle of current flow through the stator winding, the alternating magnetic field changes from 0 to +ϕ_m to 0 to -ϕ_m to 0. This original alternating magnetic field can be seen as equivalent to two component field vectors $\left(\frac{\phi_m}{2}\right)_f$ and $\left(\frac{\phi_m}{2}\right)_b$ rotating in opposite directions by one complete revolution. For 50 cycles per second supply, the alternating flux produced will make 50 cycles of flux, and hence the two component magnetic fields will rotate in opposite directions at 50 revolutions per second. This is called the synchronous speed.

This shows that an alternating field is equivalent to two revolving fields which rotate at synchronous (i.e., in synchronism with the frequency of power supply or the current flow) speed in opposite directions. This is, in brief, the concept of double recovering field theory.

We will now draw the torque-speed characteristics of the motor due to the effect of two revolving magnetic fields and draw their resultant and prove that the rotor will not have any starting torque but will rotate in either direction if an initial torque is provided.

9.4 TORQUE-SPEED CHARACTERISTIC

We have known the torque-slip or torque-speed characteristic of a three-phase induction motor where the torque is developed due to the effect of rotating magnetic field and the induced current flowing

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ward field in the clockwise direction. We will draw the torque-speed characteristics due to these two rotating fields and the resultant torque-speed characteristics with only one winding on the stator.

If we consider torque developed by forward field as positive, the torque developed by the backward field will be taken as negative. The synchronous speed for forward field is $+N_S$ and for the backward field is $-N_S$. The complete torque-speed characteristics and the resultant of these two torques have been shown in Fig. 9.3.

The curve *a* is the torque-speed characteristic due to forward field. The shape of the characteristic is similar to that developed in a three-phase induction motor, which for reference has been shown in Fig. 9.3 (b). Torque developed at starting, i.e., at zero speed, is $+T_S$. The backward field also develops torque at starting but in the reverse direction which is shown as $-T_S$. The torque-speed characteristic due to backward field has been shown by curve *b*. It must be noted that while forward field is trying to rotate the rotor in one direction, the backward field is trying to rotate in the opposite direction. Thus, while the effect of one field is motoring action, the effect of the other field on the rotor will be braking action. This has been shown by drawing the complete torque-speed characteristic due to both forward field and backward field.

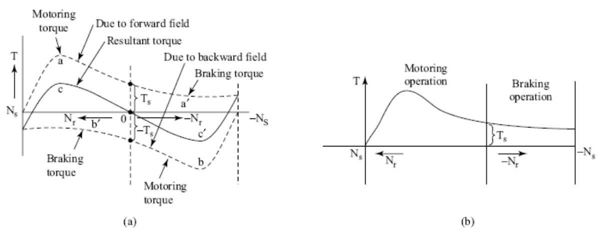

Figure 9.3 (a) Torque-speed characteristic of a single-phase induction motor without having any starting winding; (b) complete torque-speed characteristic of a three-phase induction motor

From the resultant torque-speed characteristic it is observed that the effective starting torque, T_s, is zero. However, the motor will pick up speed in whichever direction a small torque is provided by some means. The torque-speed characteristic of a single-phase induction motor for one direction of rotation has been redrawn as in Fig. 9.4.

Such a motor has to be provided with some starting torque, otherwise the rotor will not rotate.

Various methods have been developed to make a single-phase induction motor self-starting. The names of the motors have been given according to the starting methods employed. We shall describe one of the popular methods, called the split-phase method and the other used in very small motors which is known as the shaded pole method.

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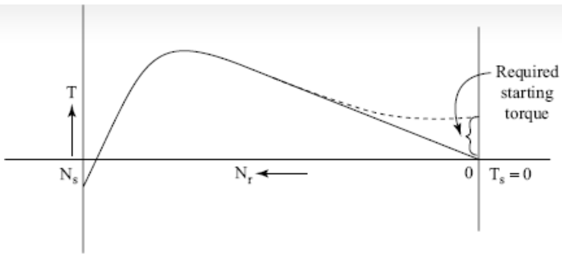

Figure 9.4 Torque-speed characteristic with no starting torque

9.5 SPLIT-PHASE INDUCTION MOTORS

Single-phase induction motors are made self-starting by using an additional winding in the stator.

Thus, in addition to the main single-phase winding in the stator a separate winding, called the auxiliary winding is provided. This auxiliary winding is also called the starting winding. This winding is placed at an angle of 90° with the main winding as shown in Fig. 9.5 (a). Both these windings are connected in parallel across the single-phase supply.

As shown in Fig. 9.5, the starting winding has been wound with thinner wires than the main winding. The auxiliary winding will have higher resistance than the main winding. If both the windings were identical with respect to their resistance and reactance, the current flowing through these windings would have been the same and the angle of lag with the voltage would also be the same. However, since the starting winding is more resistive, the angle of lag of I_a which is θ_a is less than the angle of lag of I_m, i.e., θ_m. Thus, the two currents I_a and I_m flowing through the starting winding and the main winding are split by an angle α which is equal to ($\theta_m - \theta_a$). This angle α can be increased by having variations in L and R ratio of the two windings. If we connect a capacitor, C, in the auxiliary winding circuit as has been shown in Fig. 9.5 (d), I_a can be made leading V by some angle making α nearly equal to 90°. This will make the single-phase induction motor equivalent to a two-phase induction motor but fed from a single-phase supply (in a two-phase motor there will be two-phase windings in the stator and the windings are identical. A two-phase supply is connected to the two windings. The current flowing through the windings will have a phase difference of 90°).

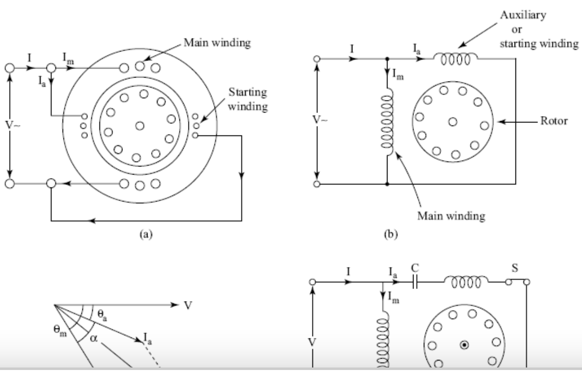

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Figure 9.5 Split-phase single-phase induction motor: (a) single-phase induction motor with main winding and starting winding; (b) connection diagram; (c) phasor diagram showing splitting of two currents, I_m and I_a; (d) split phasing with a capacitor in the starting winding circuit to increase the angle of phase splitting

When a poly-phase supply is given to a poly-phase winding, a rotating magnetic field is produced. This we have seen in the case of three-phase induction motors. For a two-phase motor also, a rotating magnetic field will be produced. A single-phase induction motor with an auxiliary winding is similar to a two-phase motor. The current flowing through the windings will have a phase difference of 90° or somewhat less than 90°.

Creating a phase split in the currents flowing through the two windings will help produce a rotating magnetic field effect on the rotor. The rotor will develop a starting torque and start rotating. The direction of rotation will depend on the way the connections of windings are made across the supply. Thus, use of auxiliary winding with or without a capacitor makes the induction motor self-starting. If the phase-split angle is more the magnitude of torque developed will be more (torque is proportional to sin α). Once the motor picks up speed we may disconnect the starting winding from the supply through a centrifugal switch or a relay. The motor will continue to develop torque due to current flow in the main winding. When the motor is stopped, the switch should close again so that while restarting, the auxiliary winding gets connected to help develop the starting torque. For improved power factor during running condition, however, the auxiliary winding can be kept connected for all the time. In that case the resultant current of I_a and I_m, i.e., I_I will have a phase angle less than the phase angle θ_m.

The torque-speed characteristic of the induction motor with the starting winding in use is shown in Fig. 9.6.

It may be noed that the torque at which the speed is zero for a poly-phase motor is the synchronous speed N_S. For a single-phase motor, torque becomes zero at a speed somewhat earlier than the synchronous speed. That is why under the same loading condition a single-phase induction motor will run at a lower speed than a poly-phase motor. The motor starts with its auxiliary winding connected to the supply. The starting torque developed, T_S, is shown as Oa. The motor starts rotating with the mechanical load connected to its shaft. When the rotor attains a speed of say N_r', the centrifugal switch disconnects the auxiliary winding and the motor continues to drive the load and attains a speed at which motor torque equals the load torque requirement, T_L. Note that N_r' is the speed at which the auxiliary winding is disconnected automatically and the motor continues to work with the main winding only.

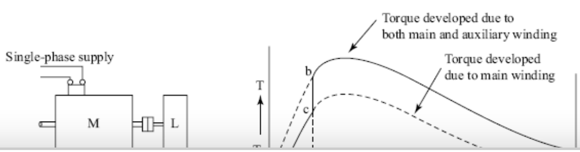

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Figure 9.6 Torque-speed characteristic of a single-phase induction motor

9.6 SHADED POLE INDUCTION MOTOR

Shaded pole-type single-phase induction motors are provided with shading rings on their poles which are the projected type of poles. The stator of such motors have projected poles like dc machines as shown in Fig. 9.7. The rotor is a squirrel cage type similar to that of split-phase-type motors. The poles are excited by giving single-phase ac supply. Single-turn thick coil in the form of a ring, called the shading ring is fitted on each side of every pole as shown. The portion of the poles where the shading ring is fitted is called the shaded portion, while the other portion is called the unshaded portion. When a single-phase supply is connected across the field windings an alternating current will flow and produce an alternating flux. An EMF will be induced in the rotor conductors due to transformer action, in the same way as in the case of split-phase-type induction motors. Since the rotor conductors are connected together, current will flow through them. If the rotor is given an initial rotation, it will pick up speed like any other single-phase motors.

Here, in shaded pole motors, the starting torque is produced due to the presence of shading rings. How the shading rings help produce a rotating magnetic field effect resulting a small starting torque to start the motor is explained as follows.

Let us assume that the current through the field winding is increasing from zero value towards its maximum value sinusoidally during the first quarter of the cycle. The flux produced will also be rising as shown in Fig. 9.7 (b). This change of flux with respect to time will induce EMF in the shading ring. Current will flow through the shading ring. This current flow through the shading ring will produce a flux around the ring. This flux, by Lenz's law will oppose the main field flux produced by the rising alternating current flowing through the field winding. The opposition of shading ring flux on the main field flux will cause reduction of flux in the shaded region. As a result there will be more flux in the unshaded region than in the shaded region. The magnetic neutral axis therefore will lie towards the unshaded region of the pole.

When current through the field winding reaches its maximum value, the rate of change of the current and hence the rate of change of the flux produced will be nearly zero. There will be no induced EMF in the shading ring and hence the shading ring will have no effect on the flux distribution in the main pole. The magnetic neutral axis will lie at the centre of the pole, i.e., at the geometrical neutral axis of the poles. Thus, by the time the current through the field coils has reached its maximum, the magnetic neutral axis has shifted from unshaded side to the centre of the poles.

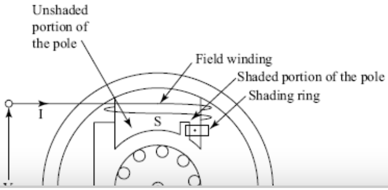

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Figure 9.7 (a) Cross-sectional view of a shaded pole-type single-phase induction motor; (b) sinusoidal flux produced by the stator current

Now when the current starts falling, the flux in the poles will also be collapsing, i.e., go on reducing. This changing flux will produce EMF in the shaded rings which will induce EMF in the rings causing flux produced around the rings. This flux, now, according to Lenz's law, will oppose the reduction of flux in the poles in the shaded region. This means, while flux in the unshaded portion will be reduced, reduction of flux in the shaded portion is delayed. The magnetic neutral axis will now shift from the centre of the pole towards the shaded portion of the pole.

Thus, we see that in every half cycle of current flow through the field winding, the magnetic neutral axis shifts from the unshaded portion of the pole to the shaded portion. This shift of magnetic axis, creates a torque on the rotor and the rotor starts rotating. Once the rotor starts rotating, it picks up speed and attains its full speed. The starting torque developed in shaded pole motors is not so strong since there is no strong rotating magnetic field effect which is produced with shaded rings. However, in applications like small cooling fans used in almost all electrical gadgets, where the starting torque requirement is low, shaded pole motors are used invariably.

9.7 SINGLE-PHASE AC SERIES MOTORS

We have known that in a dc series motor if we change the supply polarities of either the field winding or the armature winding, the direction of rotation changes. If we reverse the polarities of both the field winding and the armature winding to the power supply, the direction of rotation of a dc series motor remains unchanged. From this, it can be said that a dc series motor should also work on ac supply as well. A series motor which will work on both dc supply and single-phase ac supply is called an universal motor. Universal motors in fractional kilowatt ratings are used in many domestic electrical appliances like food mixtures, vacuum cleaners, portable drills, etc. These small motors are usually light in weight and operate at very high speeds varying from 1,500 rpm to 10,000 rpm.

It can be noticed from Fig. 9.8 that in a series motor, the line current, the field current, and the armature current is the same. The current flowing through the field windings produces a flux ϕ_d along the pole axis, i.e., the direct axis or simply the d-axis. The current flowing through the armature I_a will also produce a flux ϕ_q in the quadrature axis (Q-axis), i.e., along the brush axis.

The torque developed is expressed as

$$T = K_t \phi_d I_a \qquad \text{(i)}$$

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$$N = \frac{V - I_a(R_a + R_{se})}{K\phi_d} \qquad \text{(ii)}$$

Considering $I_a(R_a + R_{se})$ very small as compared to V,

we can write $$N \propto \frac{V}{\phi_d}$$

or, $$N \propto \frac{1}{I_a} \quad \text{since} \quad \phi_d \propto I_f \propto I_a \qquad \text{(iii)}$$

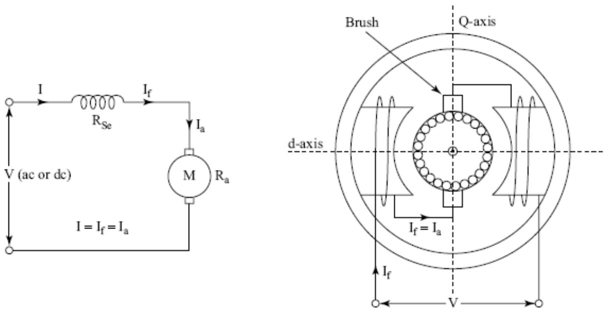

Figure 9.8 AC series motor or universal motor

Since I_a is proportional to load on the motor, we can say I_a α load.

Using the relation in (i) and (iii) above, we can draw the characteristics such as torque versus load, speed versus load, and torque versus speed as shown in Fig. 9.9.

$T \propto I_a^2$ is the equation of a parabola of the form $y = x^2$. $N \propto \frac{1}{I_a}$ is the equation of a rectangular hyperbola of the form $y \propto \frac{1}{x}$ or $xy = C$. These are shown in Figs. 9.9 (a) and (b), respectively. From the relationship of T versus I_a and N versus I_a, the relationship between T versus N can be developed as has been shown in Fig. 9.9 (c).

9.8 OPERATION OF A SERIES MOTOR ON DC AND AC (UNIVERSAL MOTORS)

The speed of a series motor on ac operation is somewhat lower than that for dc operation due to the effect of magnetic saturation, i.e., ϕ_d on ac operation will be less than ϕ_d on dc operation. Hence, the torque developed will be somewhat lower in ac operation as shown in Fig. 9.9 (c). As observed from the characteristic at Fig. 9.9 (b) at no load, the series motor will attain very high speed which may be dangerous. From Fig. 9.9 (c), it is observed that the motor develops

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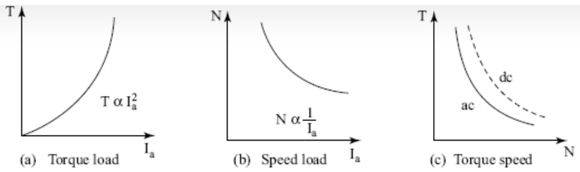

Figure 9.9 Characteristics of an ac series motor or a universal motor

For satisfactory operation of the dc series motor on both dc and ac supply, certain modifications are to be made.

AC series motors are provided with a compensating winding wound on the poles. The compensating winding is connected in series with the armature and produces a flux in a direction so as to neutralize the flux produced by the armature current, i.e., ϕ_q. Otherwise, this flux causes a reactance voltage drop which causes poor power factor and lower speed. The reduction of Q-axis armature flux improves the performance of the motor. Large ac compensated series motors are also manufactured for use in traction applications, i.e., in railways, tramways, etc.

9.9 SINGLE-PHASE SYNCHRONOUS MOTORS

These are very small motors suitable for use in clocks, timers, etc. They are available as reluctance motors and hysteresis motors. These two types of motors are described in brief as follows.

9.9.1 Reluctance Motors

Reluctance motors are single-phase motors where the stator construction is similar to that of an induction motor. That is, the stator has one main winding and one auxiliary winding. Both the windings are connected in parallel. The rotor construction is somewhat different than a single-phase induction motor. Some of the tooths of the rotor are removed so as to make the air gap between the stator and rotor non-uniform. This way the reluctance of the motor across the air gap becomes variable. The squirrel cage bars and the end rings of the rotor remain the same.

When single-phase supply is applied across the stator winding, the rotor starts rotating as an induction motor. At about 70% of the synchronous speed, the starting winding is cut off automatically. However, the rotor continues to speed up and attain synchronous speed due to reluctance torque developed. The rotor aligns itself with the synchronously rotating field and runs at synchronous speed.

In Fig. 9.10 (a) is shown the constructional details of a reluctance motor, where mm′ is the main winding while aa′ is the auxiliary winding or the starting winding. These two windings are wound at right angles to each other on the stator, exactly similar to a single-phase induction motor.

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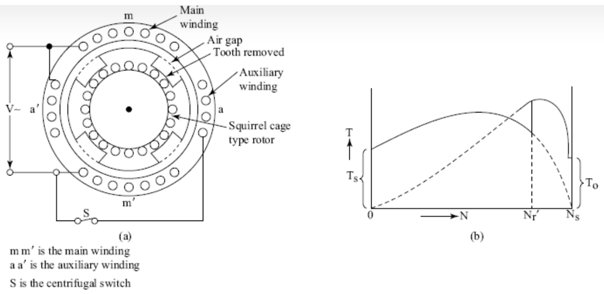

Figure 9.10 (a) Constructional details of a reluctance motor; (b) torque-speed characteristics

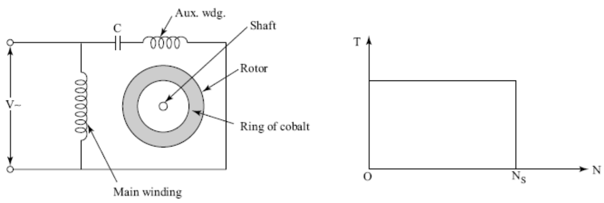

Figure 9.11 (a) Hysteresis motors; (b) torque-speed characteristic

In Fig. 9.10 (b), T_0 is the operating torque of the motor at the synchronous speed. At a speed of N_r', the centrifugal switch S is opened. The motor will continue to develop torque and run on its main winding.

Large capacity reluctance motors are made for three-phase operation with a three-phase winding on the stator.

9.9.2 Hysteresis Motors

Hysteresis motors are single-phase small size synchronous motors.

The stator windings are similar to the stator windings of single-phase induction motors. In the auxiliary winding a permanent value capacitor is connected. Like the main winding the auxiliary winding is always connected to the supply. When the stator windings are connected to a single-phase supply a rotating field is produced which is rotating at synchronous speed. There is no winding provided on the rotor. The rotor is simply made of aluminium or other non-magnetic material having a ring of a special magnetic material such as cobalt or chromium mounted on it.

The rotating field produced by the stator will induce eddy currents in the rotor. The rotor will get magnetized. But the magnetization of the rotor will lag the inducing revolving field by some angle due to the hysteresis effect. The rotating magnetic field will pull the rotor along with it and the rotor will rotate at synchronous speed. A constant torque will be developed upto the synchronous speed as shown in Fig. 9.11 (b). The performance of a single-phase hysteresis

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Stepper motors are also called the step motors. They rotate in steps by a certain angle depending upon the design. The rotor of such motors may be made of a set of permanent magnets or with a soft magnetic material with salient poles. The stator will have a set of poles with winding as shown in Fig. 9.12. The stator poles are excited by a sequence of dc pulses. The poles get magnetized one after the other in a clockwise or anticlockwise direction. Torque is developed on the rotor as the rotor magnets try to align with the stator poles.

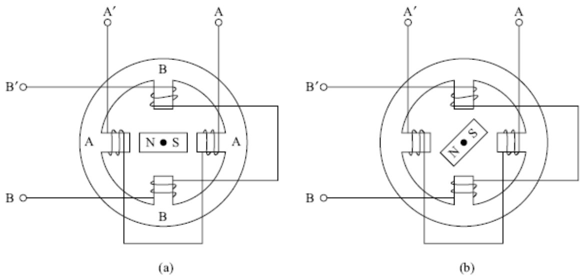

Figure 9.12 Simple illustration of a stepper motor: (a) dc pulse given to stator winding AA′; (b) dc pulse given to both the stator windings, i.e., to AA′ and BB′

In Fig. 9.12 (a) suppose a dc pulse is given to the stator field coils AA′. The stator poles AA will be magnetized. The rotor magnet will get aligned with the stator poles. Next a dc pulse is given to AA′ and BB′ coils simultaneously. The axis of the resultant magnetic field will rotate by 90° in the anticlockwise direction. The rotor magnet is trying to align with this field will also rotate by 45° in the anticlockwise direction. In the next step the BB′ coil will be energized while coil AA′ will not be supplied with any pulse. The stator magnetic field will now be along the stator field poles BB′. The rotor magnet will rotate by another 90° in the anticlockwise direction to align with the stator field. The dc pulse to the stator field poles can be sequenced such that in every step the rotor will rotate by 45°. By changing the sequence of supply to the stator field windings, the rotor can be made to rotate in steps in the clockwise direction. The step by which the rotor will rotate can be chosen by a proper design, i.e., by choosing the proper number of stator and rotor poles.

Stepper motors can be rotated to a specific angle in discrete steps, and hence such motors are used for read/write head positioning in computer floppy diskette drives. Stepper motors are also used in computer printers, optical scanners, and digital photocopiers to move the optical scanning element. The quartz analogue watches contain the smallest stepping motors.

9.11 REVIEW QUESTIONS

1. Explain the constructional details and principle of working of a split-phase-type single-phase induction motor.
2. Explain double revolving field theory and show that a single-phase induction motor without the auxiliary winding will

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5. Draw and explain the complete torque-speed characteristics of a single-phase induction motor.
6. Explain 'the speed of a single-phase induction motor is somewhat less than an equivalent three-phase motor'.
7. Show the constructional details and explain the principle of working of a shaded pole induction motor. How do you determine the direction of rotation?
8. Explain the working principle of an universal motor, draw the torque-speed characteristic, and mention its applications.
9. Explain the principle of working of a one type of single-phase synchronous motor.
10. What is a reluctance motor? How does it attain synchronous speed? Draw and explain its torque-speed characteristic.
11. Explain the construction and working principle of a hysteresis motor.
12. How do we make a single-phase induction motor self-starting?
13. Explain the working principle of a stepper motor. Mention two applications of such a motor.

Multiple Choice Questions

1. A split-phase single-phase induction motor has
    1. one stator winding
    2. two stator windings placed at an angle of 90°
    3. wound type rotor
    4. two stator windings connected in series.
2. In a resistance split-phase induction motor, phase difference between the currents flowing through the two windings of the stator is created by
    1. giving two-phase supply to the two windings
    2. creating a space-phase difference between the two windings, i.e., by placing the two windings at right angles
    3. connecting the two stator windings in series opposition across a single-phase supply
    4. having different ratios of resistance to inductive reactance for the two windings and connected across a single-phase supply.
3. When a single-phase sinusoidal ac supply is connected to a single-phase stator winding the magnetic field produced is
    1. pulsating in nature
    2. rotating in nature
    3. constant in magnitude but rotating at synchronous speed
    4. constant in magnitude but changing in direction.
4. In a split-phase capacitor-start induction motor a time-phase difference between the currents flowing through the two windings of the stator is produced by
    1. placing the two windings at an angle of 90° in the stator slots
    2. applying two-phase supply across the two windings
    3. introducing capacitive reactance in the auxiliary winding circuit
    4. connecting the two windings in series opposition across a single-phase supply.

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2. reversing the supply terminal connections
3. reversing the connections of main winding only
4. reversing the connections of auxiliary winding only.

6. A dc series motor when connected across an ac supply will
    1. develop torque in the same direction
    2. draw dangerously high current
    3. develop a pulsating torque
    4. not develop any torque at all.
7. A dc series motor will work satisfactory on ac supplying provided
    1. the yoke and the poles are completely laminated
    2. only the poles are laminated
    3. the air gap is reduced
    4. compensating poles are introduced.
8. The ceiling fan in your home has a
    1. shaded pole-type motor
    2. dc series motor
    3. universal motor
    4. capacitor-start motor.
9. In a capacitor start induction motor, the capacitor is connected
    1. in series with the main winding
    2. in series with the auxiliary winding
    3. across the supply terminals
    4. in parallel with the auxiliary winding.
10. The rotor of a stepper motor
    1. has no winding
    2. has no commutator
    3. has no slip rings
    4. all these as in (a), (b), and (c).
11. According to double revolving field theory, an alternating field can be considered equivalent to
    1. two revolving fields of constant magnitude rotating at synchronous speed in the same direction
    2. two revolving fields of constant magnitude rotating at synchronous speed but in opposite directions
    3. two revolving fields of variable magnitude rotating at synchronous speed but in opposite directions
    4. two revolving fields of variable magnitude rotating at synchronous speed in the same direction.
12. A universal motor is
    1. a series motor designed to operate on ac
    2. a series motor designed to operate on both ac and dc
    3. a series motor designed to operate on dc
    4. a dc shunt motor modified to work on both dc and ac.
13. A dc series motor has
    1. very high starting torque
    2. very low starting torque
    3. constant torque developed at all speeds
    4. constant speed-load characteristic.
14. A fractional kW ac series motor has
    1. very high speed and high starting torque
    2. constant speed and high starting torque
    3. very high speed and low starting torque
    4. maximum torque developed on full-load condition.

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3. (a)
4. (c)
5. (a)
6. (a)
7. (a)
8. (d)
9. (b)
10. (d)
11. (b)
12. (b)
13. (a)
14. (a)

PREV
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