WORKED EXAMPLES

10.1 A 3 phase, 4 pole, 440 V, 50 Hz induction motor runs with a slip of 4%. Find the rotor speed and frequency of the rotor current.

$$N_S = \frac{120\,f}{P} = \frac{120 \times 50}{4} = 1{,}500 \text{ r.p.m.}$$

$$S = \frac{N_S - N}{N_S} \quad \text{i.e.} \quad 0.04 = \frac{1{,}500 - N}{1{,}500}$$

$\therefore$ N = 1,440 r.p.m.

f' = S f = 0.04 x 50 = 2 Hz = frequency of rotor current

10.2 The frequency of the e.m.f. in the stator of a 4 pole induction motor is 50 Hz and that in the rotor is 1½ HZ. What is the slip and at what speed the motor is running?

$$f' = S\,f \quad \text{i.e.} \quad \frac{3}{2} = S \times 50, \qquad \therefore\ S = 0.03$$

$$N_S = \frac{120\,f}{P} = \frac{120 \times 50}{4} = 1{,}500 \text{ r.p.m.}$$

$$S = \frac{N_S - N}{N_S} \quad \text{i.e.} \quad 0.03 = \frac{1{,}500 - N}{1{,}500}$$

$\therefore$ N = 1455 r.p.m.

10.3 A 6 pole induction motor is connected to a 50 Hz supply. It is running at a speed of 970 r.p.m. Find the synchronous speed and the slip.

motor → N
stator → N_S

$$N_S = \frac{120\,f}{P} = \frac{120 \times 50}{6} = 1{,}000 \text{ r.p.m.}$$

$$S = \frac{N_S - N}{N_S} = \frac{1{,}000 - 970}{1{,}000} = 0.03$$

N = 970.
P = 6.

10.4 A 10 pole induction motor is supplied by a 6 pole alternator, which is driven at 1200 r.p.m. If the motor runs with a slip of 3%, what is its speed?

For alternator: $N = \dfrac{120\,f}{P}$

$$\text{i.e.} \quad 1200 = \frac{120\,f}{6}, \qquad \therefore\ f = 60 \text{ Hz}$$

For induction motor:

$$N_S = \frac{120\,f}{P} = \frac{120 \times 60}{10} = 720 \text{ r.p.m.}$$

$$S = \frac{N_S - N}{N_S} \quad \text{i.e.} \quad 0.03 = \frac{720 - N}{720}$$

$$\therefore N = 698.4 \text{ r.p.m.}$$

10.5 A 4 pole, 50 Hz induction motor has a slip of 1 % at no load. When operated at full load, the slip is 2.5%. Find the change in speed from no load to full load.

On no load:

$$N_S = \frac{120\,f}{P} = \frac{120 \times 50}{4} = 1{,}500 \text{ r.p.m.}$$

$$S = \frac{N_S - N}{N_S} \quad \text{i.e.} \quad 0.01 = \frac{1{,}500 - N_0}{1{,}500}$$

$$\therefore N_0 = \text{No load speed} = 1{,}485 \text{ r.p.m.}$$

On full load:

$$S = \frac{N_S - N}{N_S} \quad \text{i.e.} \quad 0.025 = \frac{1{,}500 - N}{1{,}500}$$

$$\therefore N = \text{Full load speed} = 1{,}462.5 \text{ r.p.m.}$$

$$\therefore \text{Change in speed} = N_0 - N = 1{,}485 - 1{,}462.5 = 22.5 \text{ r.p.m.}$$

10.6 A 12 pole, 3 phase alternator is coupled to an engine running at 500 r.p.m. It supplies an induction motor which has a full load speed of 1,440 r.p.m. Find the percentage slip and the number of poles of the motor.

N

$$f = \frac{PN}{120} = \frac{12 \times 500}{120} = 50 \text{ Hz} \quad \text{(from alternator data)}$$

N_S for induction motor is assumed to be 1,500 r.p.m. as the actual speed is 1,440 r.p.m.

$$N_S = \frac{120\,f}{P} \quad \text{i.e.} \quad 1{,}500 = \frac{120 \times 50}{P}, \quad \therefore P = 4$$

$$\% \text{ slip} = \frac{N_S - N}{N_S} \times 100 = \frac{1{,}500 - 1{,}440}{1{,}500} \times 100 = 4\%$$

10.7 A 12 pole, 3 phase, 50 Hz alternator is driven by a 440 V, 3 phase 6 pole induction motor running at a slip of 3%. Find the frequency of the e.m.f. generated by the alternator.

For induction motor:

$$N_s = \frac{120\,f}{P} = \frac{120 \times 50}{6} = 1{,}000 \text{ r.p.m.}$$

$\boxed{N = N_s(1-s)}$

$$N = N_s(1 - S) = 1000\,(1 - 0.03) = 970 \text{ r.p.m.}$$

The alternator is driven by induction motor. Hence, the speed of the alternator is 970 r.p.m.

For alternator : $f = \dfrac{PN}{120} = \dfrac{12 \times 970}{120} = 97 \text{ Hz}$

10.8 A 3 phase, 4 pole, 400V, 50 Hz induction motor runs with a slip of 4%. Find the rotor speed and frequency.

$$N_s = \frac{120\,f}{P} = \frac{120 \times 50}{4} = 1{,}500 \text{ r.p.m.}$$

$$S = \frac{N_s - N}{N_s} \quad \text{i.e.} \quad 0.04 = \frac{1{,}500 - N}{1{,}500} \qquad \therefore N = 1{,}440 \text{ r.p.m.}$$

$f' = sf$

$$f' = S\,f = 0.04 \times 50 = 2 \text{ Hz}$$

10.9 A 3 phase induction motor has 6 poles and runs at 960 r.p.m. on full load. It is supplied from an alternator having 4 poles and running at 1,500 r.p.m. Calculate the full load slip and the frequency of the rotor currents of the induction motor.

$$f = \frac{PN}{120} = \frac{4 \times 1500}{120} = 50 \text{ Hz (from alternator data)}$$

For induction motor :

$$N_s = \frac{120\,f}{P} = \frac{120 \times 50}{6} = 1{,}000 \text{ r.p.m}$$

$$S = \frac{N_s - N}{N_s} = \frac{1{,}000 - 960}{1{,}000} = 0.04 \text{ or } 4\%$$

$$f' = S\,f = 0.04 \times 50 = 2 \text{ Hz}$$

10.10 A 3 phase induction motor with 4 poles is supplied from an alternator having six poles and running at 1,000 r.p.m. Calculate (i) Synchronous speed of the

induction motor (ii) Its speed when slip is 0.04 (iii) Frequency of the rotor e.m.f., when the speed is 600 r.p.m.

i) $f = \frac{PN}{120} = \frac{6 \times 1000}{120} = 50$ Hz (from alternator data)

$$N_s = \frac{120 f}{P} = \frac{120 \times 50}{4} = 1{,}500 \text{ r.p.m}$$

ii) $N = N_s(1 - S) = 1{,}500\,(1 - 0.04) = 1{,}440$ r.p.m.

iii) $S = \frac{1{,}500 - 600}{1{,}500} = 0.6, \qquad f' = S\,f = 0.6 \times 50 = 30$ Hz

10.6 Starters for 3 Phase Induction Motors:

Three phase induction motors are self starting. But induction motors, at the time of starting, draw about 5 to 7 times the full load current and produce only 1.5 to 2.5 times the full load torque, when they are directly connected to the supply. This large initial inrush of current is due to the absence of back e.m.f. during starting. This large starting current is objectionable, as it causes large line drop and affects the operation of other connected apparatus to the line. Hence, starters are invariably used for three phase induction motors. In the case of slip-ring induction motors, resistance can be included in the rotor circuit during starting and can be removed, when the motor picks up speed. This method can't be used to start squirrel cage induction motors, as the rotors of these motors are permanently short circuited. In the case of squirrel cage induction motors, the starting current is limited by applying a reduced voltage during starting and full voltage is applied, when the motor has picked up its speed.

10.7 Methods of Starting Squirrel Cage Induction Motors:

Following are the three methods of starting squirrel cage induction motors:

i) using primary resistors

ii) using auto-transformers and

iii) using star-delta starter.

primary resistors, auto-transformers and star-delta starter

As the most frequently used starter for a three phase induction motor is star-delta starter, only this starter is discussed.