34.10. Slip

In practice, the rotor never succeeds in 'catching up' with the stator field. If it really did so, then there would be no relative speed between the two, hence no rotor e.m.f., no rotor current and so no torque to maintain rotation. That is why the rotor runs at a speed which is always less than the speed of the stator field. The difference in speeds depends upon the load on the motor.*

The difference between the synchronous speed N_s and the actual speed N of the rotor is known as ***slip***. Though it may be expressed in so many revolutions/second, yet it is usual to express it as a percentage of the synchronous speed. Actually, the term '***slip***' is descriptive of the way in which the rotor 'slips back' from synchronism.

$$\% \text{ slip } s = \frac{N_s - N}{N_s} \times 100$$

Sometimes, $N_s - N$ is called the ***slip speed.***

Obviously, rotor (or motor) speed is $N = N_s (1 - s)$.

It may be kept in mind that revolving flux is rotating synchronously, relative to the stator (*i.e.* stationary space) but at slip speed relative to the rotor.

34.11. Frequency of Rotor Current

When the rotor is stationary, the frequency of rotor current is *the same as the supply frequency.* But when the rotor starts revolving, then the frequency depends upon the relative speed or on slip-speed. Let at any slip-speed, the frequency of the rotor current be f'. Then

$$N_s - N = \frac{120 f'}{P} \qquad \text{Also,} \quad N_s = \frac{120 f}{P}$$

Dividing one by the other, we get, $\frac{f'}{f} = \frac{N_s - N}{N_s} = s$ $\qquad \therefore \quad f' = sf$ 1

As seen, rotor currents have a frequency of $f' = sf$ and when flowing through the individual phases of rotor winding, give rise to rotor magnetic fields. These individual rotor magnetic fields produce a combined rotating magnetic field, whose speed relative to rotor is

$$= \frac{120\, f'}{P} = \frac{120\, sf}{P} = sN_S$$

However, the rotor itself is running at speed N with respect to space. Hence,

speed of rotor field in *space* = speed of rotor magnetic field relative to rotor + speed of rotor relative to space

$$= sN_s + N = sN_s + N_s\,(1-s) = N_s$$

It means that no matter what the value of slip, rotor currents and stator currents each produce a sinusoidally distributed magnetic field of constant magnitude and constant space speed of N_s. In other words, both the rotor and stator fields rotate synchronously, which means that they are stationary with respect to each other. These two synchronously rotating magnetic fields, in fact, superimpose on each other and give rise to the actually existing rotating field, which corresponds to the magnetising current of the stator winding.

Example 34.1. *A slip-ring induction motor runs at 290 r.p.m. at full load, when connected to 50-Hz supply. Determine the number of poles and slip.*

(Utilisation of Electric Power AMIE Sec. B 1991)

Solution. Since N is 290 rpm; N_s has to be somewhere near it, say 300 rpm. If N_s is assumed as 300 rpm, then $300 = 120 \times 50/P$. Hence, $P = 20$. $\therefore\ s = (300-290)/300 = 3.33\%$

Example 34.2. *The stator of a 3-φ induction motor has 3 slots per pole per phase. If supply frequency is 50 Hz, calculate*

(*i*) *number of stator poles produced and total number of slots on the stator*

(*ii*) *speed of the rotating stator flux (or magnetic field).*

Solution. (*i*) $P = 2n = 2 \times 3 =$ **6 poles**

Total No. of slots = 3 slots/pole/phase × 6 poles × 3 phases = **54**

(*ii*) $N_s = 120f/P = 120 \times 50/6 =$ **1000 r.p.m.**

Example 34.3. *A 4-pole, 3-phase induction motor operates from a supply whose frequency is 50 Hz. Calculate :*

(*i*) *the speed at which the magnetic field of the stator is rotating.*

(*ii*) *the speed of the rotor when the slip is 0.04.*

(*iii*) *the frequency of the rotor currents when the slip is 0.03.*

(*iv*) *the frequency of the rotor currents at standstill.*

(Electrical Machinery II, Banglore Univ. 1991)

Solution. (*i*) Stator field revolves at synchronous speed, given by

$N_s = 120f/P = 120 \times 50/4 =$ **1500 r.p.m.**

(*ii*) rotor (or motor) speed, $N = N_s(1-s) = 1500(1-0.04) =$ **1440 r.p.m.**

(*iii*) frequency of rotor current, $f' = sf = 0.03 \times 50 = 1.5$ r.p.s = **90 r.p.m**

(*iv*) Since at standstill, $s = 1$, $f' = sf = 1 \times f = f =$ **50Hz**

Example 34.4. *A 3-φ induction motor is wound for 4 poles and is supplied from 50-Hz system. Calculate (i) the synchronous speed (ii) the rotor speed, when slip is 4% and (iii) rotor frequency when rotor runs at 600 rpm.* **(Electrical Engineering-I, Pune Univ. 1991)**

Solution. (*i*) $N_s = 120\,f/P = 120 \times 50/4 = 1500$ rpm

(*ii*) rotor speed, $N = N_s(1-s) = 1500\,(1-0.04) =$ **1440 rpm**

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(*iii*) when rotor speed is 600 rpm, slip is

$$s = (N_S - N)/N_s = (1500 - 600)/1500 = 0.6$$

rotor current frequency, $f' = sf = 0.6 \times 50 =$ **30 Hz**

Example 34.5. *A 12-pole, 3-phase alternator driven at a speed of 500 r.p.m. supplies power to an 8-pole, 3-phase induction motor. If the slip of the motor, at full-load is 3%, calculate the full-load speed of the motor.*

Solution. Let N = actual motor speed; Supply frequency, $f = 12 \times 500/120 = 50$ Hz. Synchronous speed $N_s = 120 \times 50/8 = 750$ r.p.m.

$$\% \text{ slip } s = \frac{N_S - N}{N} \times 100 \; ; \quad 3 = \frac{750 - N}{750} \times 100 \qquad \therefore N = \textbf{727.5 r.p.m.}$$

Note. Since slip is 3%, actual speed N is less than N_s by 3% of N_s *i.e.* by $3 \times 750/100 = 22.5$ r.p.m.

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