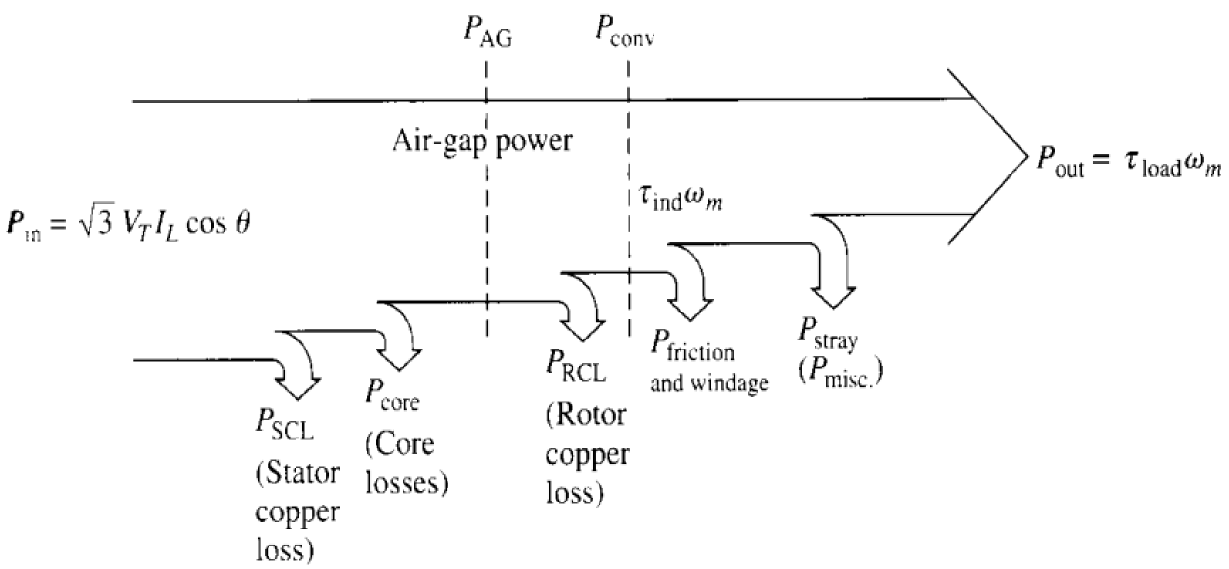
2-8 Power and Energy Diagram: -



$$P1 = m1\, I1\, V1\ \cos\theta 1 = 3I1\, V1\ \cos\theta 1 = \sqrt{3}\, I_L V_L \cos\theta\, 1$$

$$P_M = I2e^2 R\mu = I2e^2\ R2e\ \frac{1-S}{S}\ \ , I2e = \frac{E2e}{Z2es}$$

$$P_M = E2e(1-s)I2e\ \frac{\frac{R2e}{s}}{Z2e} = (1-s)I2e\ E2e\cos\theta 2e$$

Since $.\frac{R2e/s}{Z2e}$

$$P_M = \ I2e\ E2e\cos\theta 2 - S\ E2e\ I2e\ \cos\theta 2e = Pem - Pcu2$$

$$P_M = Pem - sPem = (1-s)Pem$$

$$Pcu2 = I2e^2 R2e = \frac{E2e}{Z2e} I2e\ R2e = E2e\ I2e\ \frac{R2e}{Z2es}$$

$$= sE2e\ I2e\ \frac{\frac{R2e}{s}}{Z2es} = \mathrm{s\ E2e\ I2e\ \cos\theta 2}$$

$$Pem = \ P_M + \ Pcu2 = I2e^2\frac{R2e}{s} = I2e^2\left(R2e + R2e\ \frac{1-s}{s}\right) = \frac{Pcu2}{s}$$

$$P2 = P_M - (Pfw + Padd); Pem = P1 - Pcu1 - Pfe$$

$$P_M = Pem - \ Pcu2 = P1 - Pcu1 - Pfe - Pcu2$$

$$P2 = P1 - (Pcu1 + Pcu2 + Pfe + Pfw + \ Padd)$$

$$Tem = \frac{Pem}{\omega 1} = \frac{60}{2\pi ns} Pem = \frac{P}{2\pi F1} Pem$$

$$Tem = \frac{P_M}{\omega 2} = \frac{60}{2\pi n} P_M = \frac{P}{2\pi F2} P_M$$

$$Pcu2 = Pem - P_M = Tem(\omega 1 - \omega 2) = s(\omega 1\, Tem) = sPem$$

Where: $s = \frac{\omega 1 - \omega 2}{\omega 1}$

$$Tem = \frac{Pcu2}{s\omega 1}, \quad s = \frac{Pcu2}{\omega 1\, Tem} = \frac{Pcu2}{Pem} = \frac{I2e^2\, R2e}{I2e^2\, R2e/s}$$

$$P_M = I2e^2\, R2e\, \frac{1-s}{s} = Pcu2\, \frac{1-s}{s} = sPem\left(\frac{1-s}{s}\right) = (1-s)Pem$$

Ex1) A3-phase ,4pole,50HZ IM ,the impedance of the star connected rotor winding is(0.2+j3)per phase the no-load induced emf between slip-rings is 220v ,find the rotor current and power factor at rated.

Sol:

$$n1 = ns = \frac{60F}{P} = \frac{60 \times 50}{2} = \frac{3000}{2} = 1500\, rpm$$

$$s = \frac{n1 - n}{n1} = \frac{1500 - 1455}{1500} = 0.03$$

$$E2 = \frac{220}{\sqrt{3}} = 127V$$

$$E2S = SE2 = 0.03 \times 127 = 3.81V$$

$$Z2S = \sqrt{R2^2 + (SX2)^2} = \sqrt{0.2^2 + (0.03 \times 3)^2} = 0.22\Omega$$

$$I2 = \frac{E2S}{Z2S} = \frac{3.81}{0.22} = 17.32A$$

$$\cos\theta 2 = \frac{R2}{Z2} = \frac{0.2}{0.22} = 0.909$$

Ex2) A 3-phase ,4-pole,380v,50HZ IM with rotor impedance of (0.1+j0.6) Ω/phase, both winding is λ-connected with T1/T2=1.5. find the stator current if the excitation current is(1-j10) A, and motor speed is 1440 rpm, neglect the primary impedance(Z1=0)

SOL:

$$n1=\frac{60F1}{P}=1500rpm, s=\frac{1500-1440}{1500}=0.04$$

$$R2e=0.1\times1.5^2=0.225\Omega\ , X2e=0.6\times1.5^2=1.35\Omega$$

$$Vphas=\frac{Vline}{\sqrt{3}}=\frac{380}{\sqrt{3}}=220v\ , Z2e=\frac{R2e}{s}+jX2e=\frac{0.225}{0.04}+j1.35$$

$$I2e=\frac{v}{z2e}=\frac{220}{5.625+j1.35}=37-j8.87A$$

$$I1=Ie+I2e=(1-j10)+(37-j8.87)=38-j18.87$$

$$I1=42.43$$

Ex3) A3-phase ,6-pole,440v ,50HZ IM. the parameters of its star connected winding are,R1=R2e=0.1 ,X1=X2e=0.4 ,Ye=0.008-j0.06Ω/phase. find the current and power factor at 50% the rated load at which the slip is 0.04.use the exact equivalent cct.

Sol:

$$Rm=R2e\frac{1-s}{s}=0.1\ \frac{1-0.04}{0.04}=2.4\Omega$$

$$Vp=\frac{440}{\sqrt{3}}=254v$$

$$y2e=\frac{1}{z2e}=\frac{1}{2.5+j0.4}=0.39-j0.06$$

$$yab=ye+y2e=(0.008-j0.06)+(0.39+j0.06)=0.398-j0.66$$

$$Zab=\frac{1}{yab}=\frac{1}{0.398-j0.66}=\frac{0.398-j0.66}{0.398^2-0.66^2}=0.67+j1.11$$

$$Zt=Z1+Zab=(0.1+j0.4)+(0.67+j1.11)=0.77+j1.51$$

$$I1=\frac{Vphase}{Zt}=\frac{254}{0.77+j1.51}=68-j133.5$$

$I1 = 150A \ , \cos\theta 1 = \frac{Ia}{I1} = \frac{68}{150} = 0.45$

Ex4) A3-phase, 4pole, 50H_Z IM, at full-load delivers,T_2=120N.M torque at 0.03slip.find the efficiency if the total stator losses are (0.1P_2)and P_{fw}=0.01P2

Sol:

$$n1 = ns = \frac{60F1}{P} = \frac{60 \times 50}{2} = 1500\, rpm$$

$$s = \frac{n1 - n}{n1} = \frac{1500 - n}{1500} = 0.03 \rightarrow \text{n} = 1455 \text{ rpm}$$

$$or\ n = (1 - s)n1 = (1 - 0.03) \times 1500 = 1455rpm$$

The useful out put power is

$$P2 = \omega.T = \frac{2\pi n}{60} \times T2 = 2\pi\frac{1455}{60} \times 120 = 18275\omega$$

$$P\mu = P2 + Pfw = 1.01P2 = 1.01 \times 18275 = 18458\omega$$

$$Pem = P\mu\frac{n1}{n} = 18458 \times \frac{1500}{1455} = 19029$$

$$or\ Pem = \frac{P\mu}{1 - s} = \frac{18458}{1 - 0.03} = 19029\omega$$

The total input power to the motor is :

$$P1 = Pem + Pstator = 19029 + 0.1 \times 18275 = 20932\omega$$

And efficiency

$$\eta = \frac{18275}{20932} = \frac{P2}{P1}$$