Equivalent circuit of a capacitor run motor

In capacitor-run and capacitor-start capacitor-run induction motor, the auxiliary winding stays in operation all the time and the motor operates as a two-phase induction motor. As shown in figure (19), the main winding and auxiliary winding are excited by currents i_m and i_a.

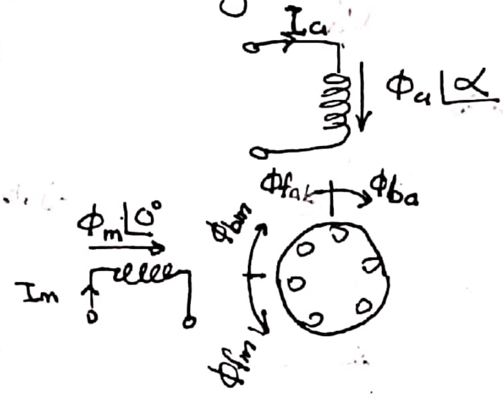
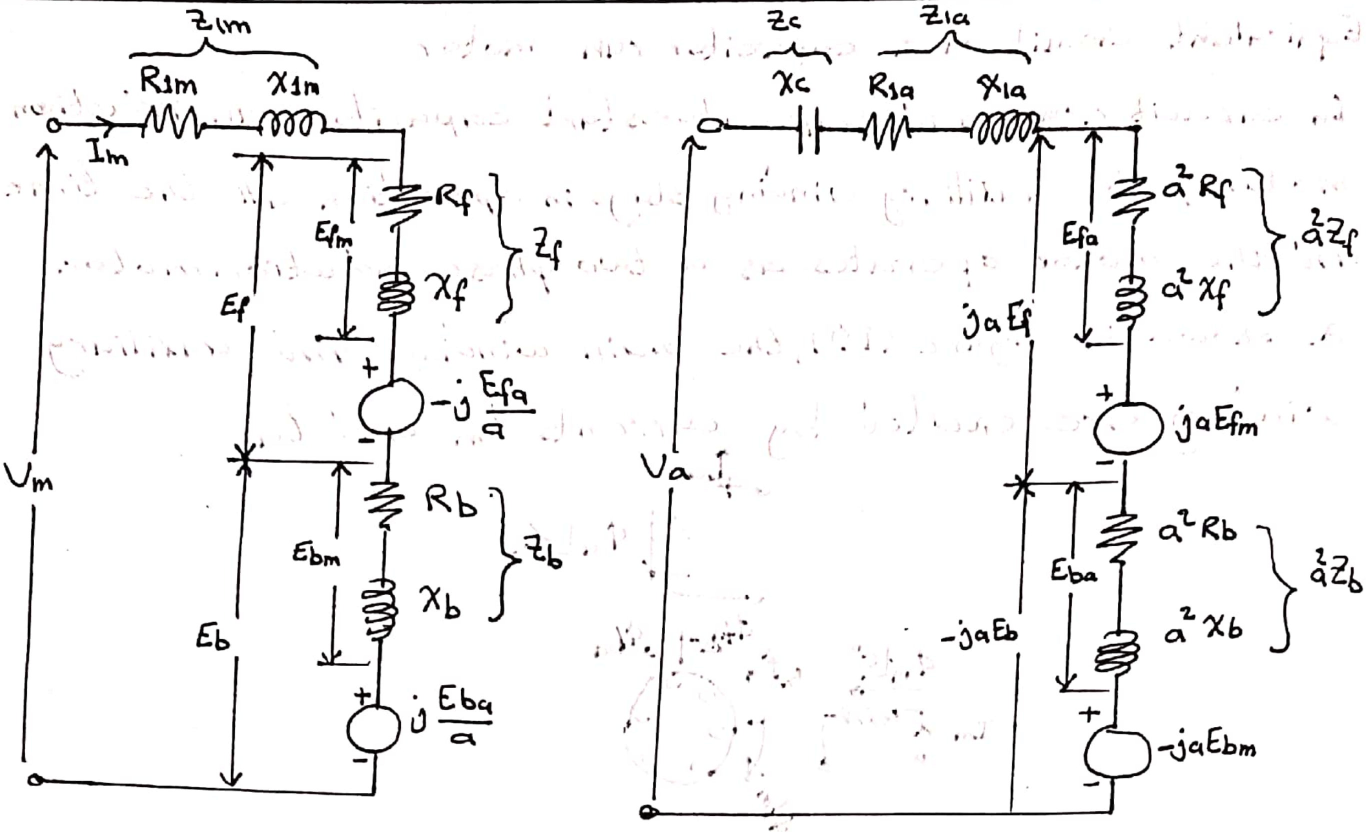


Fig (19)

The main flux Φ_m can be resolved into two revolving fluxes Φ_{fm} (forward revolving) and Φ_{bm} (backward revolving). Simillarly, the auxiliary winding flux Φ_a is resolved into two revolving fluxes Φ_{fa} and Φ_{ba}. These four revolving fluxes all induce voltages in the two winding.

The main winding can be represented by the equivalent circuit shown in figure (20a) where $a = N_a/N_m$. The auxiliary winding is represented by an equivalent circuit shown in figure (20b).



(a) (b)

Figure(20)

$$V_m = (Z_{1m} + Z_f + Z_b)\, I_m - j\,\frac{E_{fa}}{a} + j\,\frac{E_{ba}}{a} \quad \text{------ (1)}$$

$$V_a = (Z_c + Z_{1a} + a^2 Z_f + a^2 Z_b)\, I_a + j a E_{fm} - j a E_{bm} \quad \text{--- (2)}$$

where $Z_{1m} = R_{1m} + j X_{1m}$

$Z_{1a} = R_{1a} + j X_{1a}$

$Z_c = -j X_c$

reffering rotor to the main stator winding = R_f

$R_f = R \cdot \frac{N_m}{N_r}$

reffering rotor to the auxiliary stator winding = $R_f \cdot \frac{N_a}{N_m}$

$= R \cdot \frac{N_m}{N_r} \cdot \frac{N_a}{N_m}$

$= R \cdot \frac{N_a}{N_r}$

Now:

$$E_{fa} = I_a \cdot a^2 Z_f \quad \text{---- (3)}$$

$$E_{ba} = I_a \cdot a^2 Z_b \quad \text{--- (4)}$$

$$E_{fm} = I_m \cdot Z_f \quad \text{--- (5)}$$

$$E_{bm} = I_m \cdot Z_b \quad \text{--- (6)}$$

substitute equations (3) to (6) in (1) & (2):

$$V_m = (Z_{1m} + Z_f + Z_b) I_m - ja(Z_f - Z_b) I_a \quad \text{—(7)}$$

$$V_a = ja(Z_f - Z_b) I_m + (Z_c + Z_{1a} + a^2 Z_f + a^2 Z_b) I_a \quad \text{---(8)}$$

let $Z_M = Z_{1m} + Z_f + Z_b$

$Z_A = Z_{1a} + Z_c + a^2 Z_f + a^2 Z_b$

hence

$$V_m = Z_M I_m - ja(Z_f - Z_b) I_a \quad \text{—(9)}$$

$$V_a = ja(Z_f - Z_b) I_m + Z_A I_a \quad \text{---(10)}$$

From (9) & (10), I_m & I_a can be solved:

$$I_m = \frac{V_m Z_A + ja V_a (Z_f - Z_b)}{Z_m Z_A - a^2 (Z_f - Z_b)^2} \quad \text{---(11)}$$

$$I_a = \frac{V_a Z_m - ja V_m (Z_f - Z_b)}{Z_m Z_A - a^2 (Z_f - Z_b)^2} \quad \text{----(12)}$$

equations (7) & (8) can be written as:-

$$V_m = I_m Z_{1m} + (I_m - ja I_a) Z_f + (I_m + ja I_a) Z_b \quad \text{—(13)}$$

$$V_a = I_a (Z_{1a} + Z_c) + ja (I_m - ja I_a) Z_f - ja (I_m + ja I_a) Z_b \quad \text{--(14)}$$

Now:-

$$I_f = I_m - ja I_a \quad \text{—(15)}$$

$$I_b = I_m + ja I_a \quad \text{—(16)}$$

$P_{gf} = I_f^2 R_f$

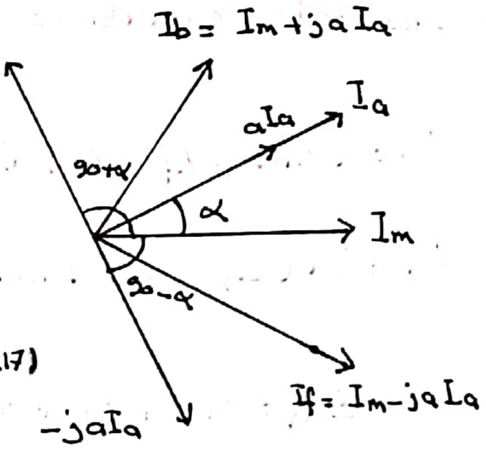
$T_f = I_f^2 R_f$ synchronous watt

$= |I_m - jaI_a|^2 R_f$

$= [|I_m|^2 + |(aI_a)|^2 + 2a|I_a||I_m| \cos(90 - \alpha)] \cdot R_f$

$= [|I_m|^2 + |aI_a|^2 + 2a|I_a||I_m| \sin\alpha] \cdot R_f$ --(17)

in synchronous watt



$P_{gb} = I_b^2 R_b$

$T_b = I_b^2 R_b$ in synchronous watt

$= |I_m + jaI_a|^2 R_b$

$= [|I_m|^2 + |aI_a|^2 + 2a|I_a||I_m| \cos(90 + \alpha)] \cdot R_b$

$= [|I_m|^2 + |aI_a|^2 - 2a|I_a||I_m| \sin\alpha] \cdot R_b$ syn. watt --(18)

The resultant electromagnetic torque in synchronous watt is

$T = T_f - T_b$

$P_{gf} - P_{gb} = I_f^2 R_f - I_b^2 R_b$

$= T$ in synchronous watt

$= [|I_m|^2 + |aI_a|^2](R_f - R_b) + 2a|I_a||I_m|(R_f + R_b) \sin\alpha$

------ (19)

$P_m = (1-s)(P_{gf} - P_{gb})$

$RCL = s P_{gf} + (2-s) P_{gb}$

at starting $(s=1)$: $R_f = R_b$ hence starting torque T_s is:-

$T_s = 2a|I_a||I_m|(R_f + R_b) \sin\alpha$ syn. watt --- (20)

$$T_s = \frac{2a|I_a||I_m|(R_f + R_b) \sin\alpha}{\omega_s} \quad N \cdot m \qquad \text{--- (21)}$$