EQUIVALENT CIRCUIT OF SINGLE PHASE INDUCTION MOTOR

The double revolving field theory can be effectively used to obtain the equivalent circuit of a single phase induction motor. The method consists of determining the values of both the fields clockwise and anticlockwise at any given slip. When the two fields are known, the torque produced by each can be obtained. The difference between these two torques is the net torque acting on the rotor.

Imagine the single phase induction motor is made up of one stator winding and two imaginary rotor windings. One rotor is rotating in forward direction i.e. in the direction of rotating magnetic field with slip s while other is rotating in backward direction i.e. in direction of oppositely directed rotating magnetic field with slip 2 - s.

To develop the equivalent circuit, let us assume initially that the core loss is absent.

Without core loss

Let the stator impedance be Z Ω

$Z = R_1 + j X_1$

Where R_1 = Stator resistance X_1 = Stator reactance

And X_2 = rotor reactance referred to stator

R_2 = rotor resistance referred to stator

Hence the impedance of each rotor is $r_2 + j x_2$ x_2 = where

$X_2/2$

The resistance of forward field rotor is r_2/s while the resistance of backward field rotor is $r_2/(2 - s)$. The r_2 value is half of the actual rotor resistance referred to stator.

As the core loss is neglected, R_o is not existing in the equivalent circuit. The x_o is half of the actual magnetizing reactance of the motor. So the equivalent circuit referred to stator is shown in the Fig.5.4.1

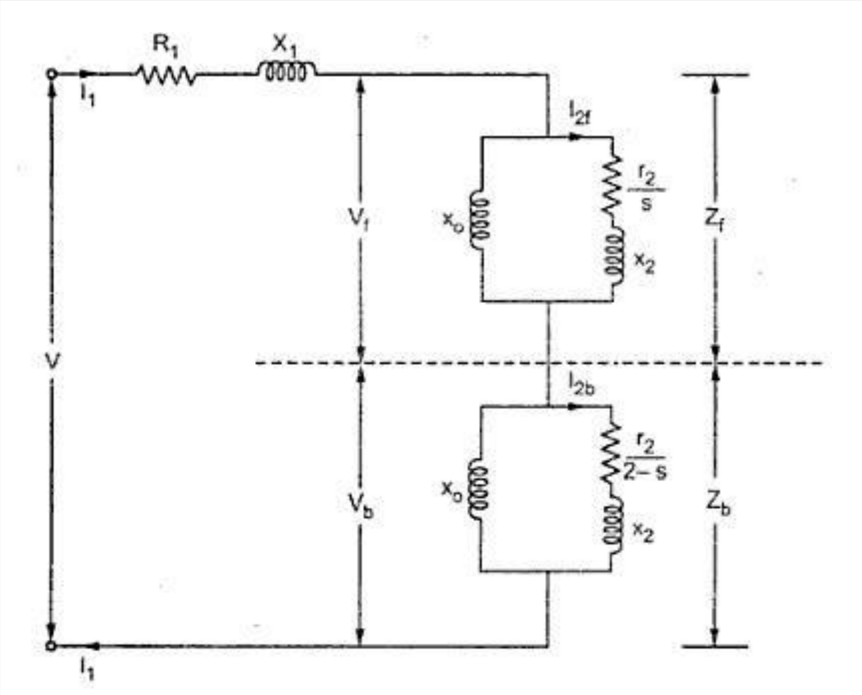

Fig. 5.4.1 Equivalent circuit without core loss

Now the impedance of the forward field rotor is Z_f which is parallel combination of $(0 + j\ x_o)$ and $(r_2 /s) + j\ x_2$

$$\therefore \qquad Z_f = \frac{j x_o\left[\left(\frac{r_2}{s}\right)+j x_2\right]}{\frac{r_2}{s}+j(x_o+x_2)}$$

While the impedance of the backward field rotor is Z_b which is parallel combination of $(0 + j\ x_o)$ and $(r_2 / 2\text{-}s) + j\ x_2$.

$$\therefore \qquad Z_b = \frac{j x_o\left[\left(\frac{r_2}{2-s}\right)+j x_2\right]}{\frac{r_2}{2-s}+j(x_o+x_2)}$$

Under standstill condition, s = 1 and 2 - s = 1 hence $Z_f = Z_b$ and hence $V_f = V_b$. But in the running condition, V_f becomes almost 90 to 95% of the applied voltage.

∴ $Z_{eq} = Z_1 + Z_f + Z_b$ = Equivalent impedance

Let I_{2f} = Current through forward rotor referred to stator

and I_{2b} = Current through backward rotor referred to stator

∴ $I_{2f} = /((r_2/s) + j\ x_2)$ where $V_f = I_1$ x Z_f

and $I_{2b} = /((r_2/2\text{-}s) + j\ x_2)$

P_f = Power input to forward field rotor

$= (I_{2f})^2\ (r_2/s)$ watts

P_b = Power input to backward field rotor

$= (I_{2b})^2\ (r_2/2\text{-}s)$ watts

$P_m = (1 - s)\{$ Net power input$\}$

$= (1 - s)\ (P_f - P_b)$ watts

$P_{out} = P_m$- mechanical loss - core loss

∴ T_f = forward torque = $P_f /(2\pi N/60)$ N-m

Tb = backward torque = $P_b /(2\pi N/60)$ N-m T = net torque = T_f
- T_b

while T_{sh} = shaft torque = $P_{out} /(2\pi N/60)$ N-m

%η = (net output / net input) x 100

With core loss

If the core loss is to be considered then it is necessary to connect a resistance in parallel with, in an exciting branch of each rotor is half the value of actual core loss resistance. Thus the equivalent circuit with core loss can be shown as in the Fig. 5.4.2

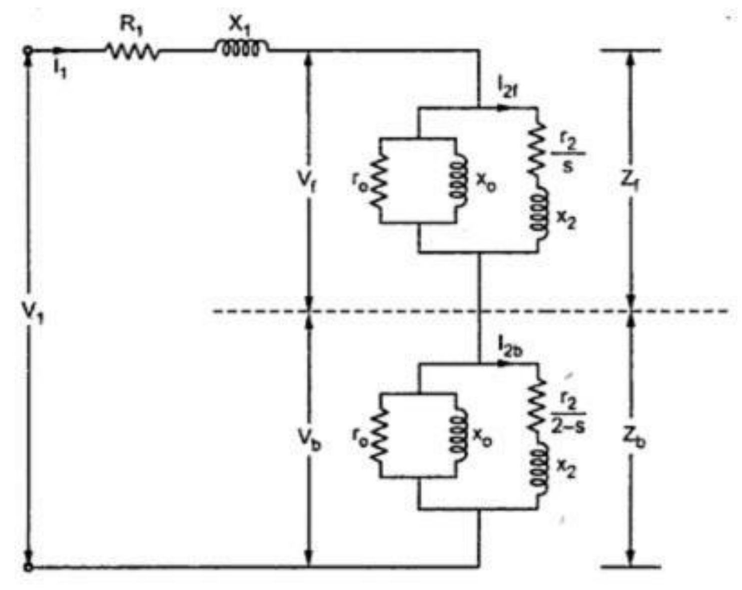

Fig. 5.4.2 Equivalent circuit with

Let Z_{of} = Equivalent impedance of exciting branch in forward rotor

$= r_o \| (j\, x_o)$

and Z_{ob} = Equivalent impedance of exciting branch in backward rotor

$= r_o \| (j\, x_o)$

$\therefore$ $Z_f = Z_{of} \| (r_2/s + j\, x_2)$

All other expressions remains same as stated earlier in case of equivalent circuit without core loss.