KING FAHD UNIVERSITY OF PETROLEUM & MINERALS
ELECTRICAL ENGINEERING DEPARTMENT
EE-462 ELECTRICAL MACHINES

Term: 012

Experiment # 7
DETERMINATION OF INDUCTION MOTOR PARAMETERS

OBJECTIVE

To determine the electrical parameters of a 3-φ induction motor (primary and secondary resistance and reactance and the magnetization branch values).

INTRODUCTION

A. NO LOAD TEST

Rated balanced voltage at rated frequency is applied to the stator, and the motor is allowed to run on no-load. Input power, voltage, and current are measured and then reduced to per-phase values, denoted by P_0, V_0, and I_0 respectively. When the machine runs on no-load, the slip is close to zero, and the circuit to the right of the shunt branch in figure l is taken to be an open circuit. Thus the equivalent circuit to the non-load test conditions is given in figure 2.a or equivalently in figure 2.b, in which the shunt branch is replaced by an equivalent series impedance to facilitate the evaluation of the

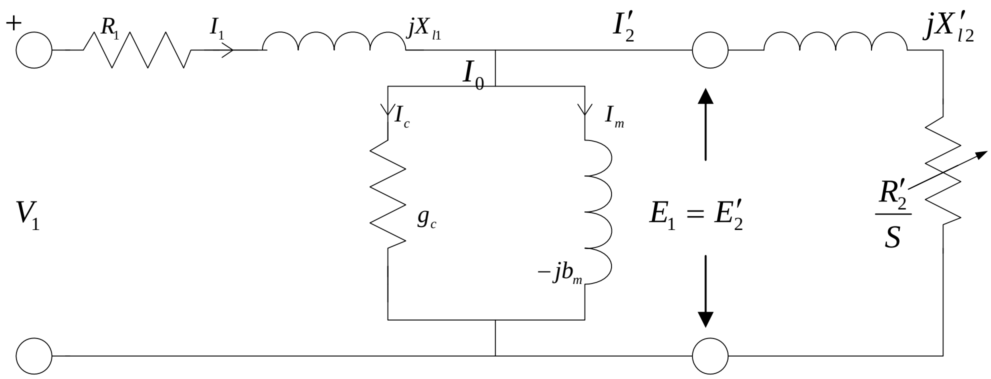

Figure 1. Per-phase equivalent circuit of a poly-phase induction motor referred to the stator

motor parameters.
The conductance g_c in figure 2.a takes into account not only the losses from the stator core but also from windage and friction. Because of the relatively low value of rotor frequency, the rotor core loss is practically negligible at no-load. From figure 2.b, it follows that

$$R_0 = R_1 + R_M = \frac{P_0}{I_0^2} \qquad \dots \text{ eqn (1).}$$

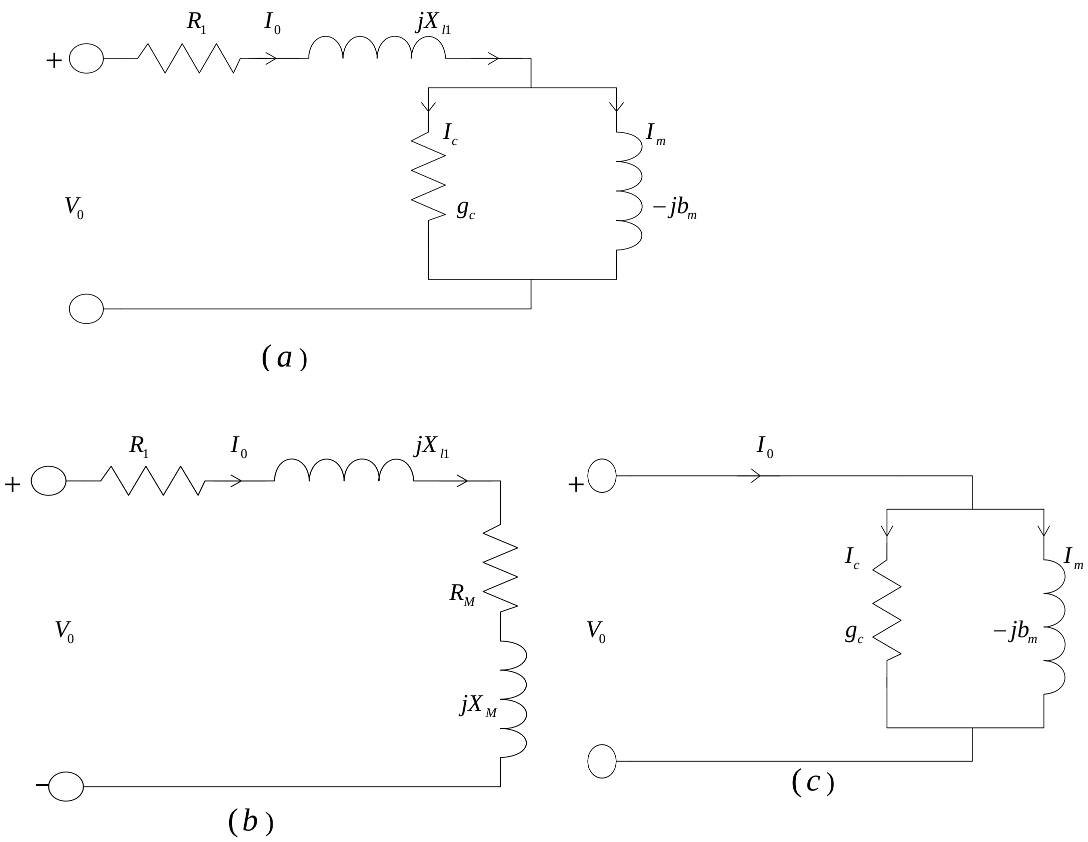

Figure 2. Per-phase equivalent circuits of a poly-phase induction motor corresponding to the no-load test condition ($S \approx 0$)

$$Z_0 = \frac{V_0}{I_0} \qquad \text{…. eqn(2).}$$

$$X = X_{l1} + X_M = \sqrt{Z_0^{\,2} - R_0^{\,2}} \qquad \text{…. eqn(3).}$$

No load power factor = $\cos\varphi_0 = \dfrac{P_0}{V_0 I_0}$ …. eqn(4).

In which R_1 is the stator resistance per phase; the series resistance $R_M << X_M$; and $X_M \approx \dfrac{1}{b_M}$.

The
rotational losses given by the sum of the friction, windage, and core losses are found on a per-phase basis by subtracting the stator copper loss from the noload power input:

$$P_{r0} = P_0 - I_0^{\,2} R_1 \qquad \text{…. eqn(5).}$$

An approximate per-phase equivalent circuit, shown in figure 2.c is sometimes used for the no-load test conditions, in which case, the calculation of shunt-branch parameters becomes much simpler — more like a transformer.

B. BLOCKED-ROTOR TEST

In this test, the rotor of the induction motor is blocked so that the slip is equal to unity, and a reduced voltage is applied to the machine stator terminals so that the rated current flows through the stator windings. The input power, voltage, and current values are recorded and reduced to per-phase values, denoted respectively by P_s, V_s, and I_s. The iron losses are assumed to be negligible in this test. The equivalent circuit corresponding to the blocked-rotor test conditions is then given by figure 3.a or equivalently by figure 3.b. If we consider the shunt branch of the circuit shown in figure 3.a to be absent, as in a transformer short-circuit test, the calculations become much simpler because X_2'' and R_2'' are then equal to X_{l2}' and R_2' respectively. From figure 3.b, it then follows that

$$R_{eq} = R_1 + R_2'' = \frac{P_S}{I_S^{\ 2}} \qquad \text{… eqn (6).}$$

$$Z_{eq} = \frac{V_S}{I_S} \qquad \text{…. eqn(7).}$$

$$X_{eq} = X_{l1} + X_2'' = \sqrt{Z_{eq}^{\ 2} - R_{eq}^{\ 2}} \qquad \text{…. eqn(8).}$$

$$\cos\varphi_S = \frac{P_S}{V_S I_S} \qquad \text{…. eqn(9).}$$

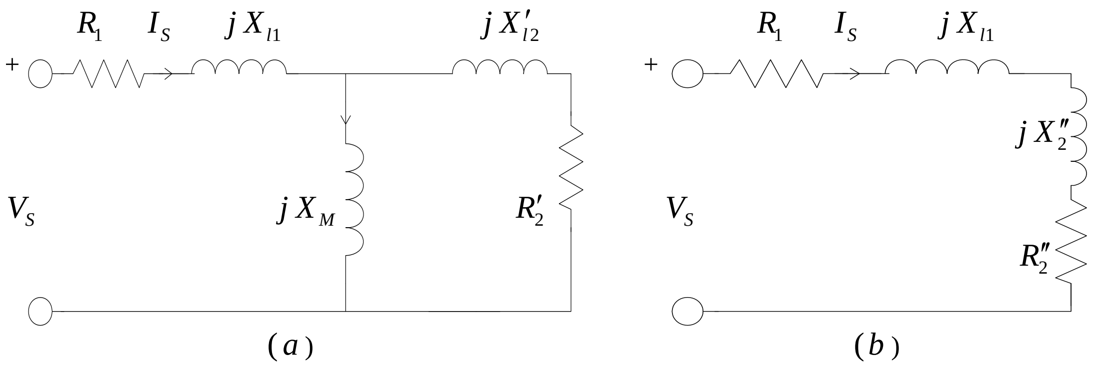

Figure 3. Per phase equivalent circuits of a polyphase induction motor corresponding to the blocked-rotor test conditions ($S = 1$)

When the classification of the motor is not known, assume that

$$X_{l2} = X_{l2}' = 0.5\,X_{eq} \qquad \text{…. eqn. (10).}$$

The magnetizing reactance X_M can now be evaluated from equation 3. The value of R_2' requires a closer approximation than that of X_{l2}' because, in the running range, $R_2' S >> (X_{l1} + X_{l2}')$ and R_2' has a correspondingly greater effect on the performance of the motor within that range. From the equivalent circuits of figures 3.a and 3.b, it follows that

$$R_2'' + jX_2'' = \frac{(R_2' + jX_{l2}')\,jX_M}{R_2' + j(X_{l2}' + X_M)} \qquad \text{….. eqn (11).}$$

Equating the real parts of both sides, it can be shown that

$$R_2'' = \frac{R_2'\ X^2{}_M}{(R_2')^2 + (X_{l2}' + X_M)^2} \qquad \text{…… eqn (12).}$$

Since $R_2' << X_{l2}' + X_M$, equation 12 can be approximated as

$$R_2'' \approx \frac{R_2'\ X^2{}_M}{(X_{l2}' + X_M)^2} \qquad \text{…. eqn (13).}$$

Substituting from equation 6 that $R_2'' = R_{eq} - R_1$, we get

$$R'_2 = (R_{eq} - R_l)\frac{(X'_{l2} + X_M)^2}{X_M^2} \quad \text{…. eqn (14).}$$

If X_M is much larger than X'_{l2}, R'_2 is nearly equal to $R_{eq} - R_l$ or R''_2 otherwise R'_2 is somewhat larger than R''_2.

C. DC TEST

By connecting a DC supply to the 3φ induction motor as shown in figure 4 (while the motor is at standstill), the stator resistance per phase can be calculated as $R_1 = \frac{V_{dc}}{2I_{dc}}$ (for star connected stator) and $R_1 = \frac{3V_{dc}}{2I_{dc}}$ (for Δ connected stator).

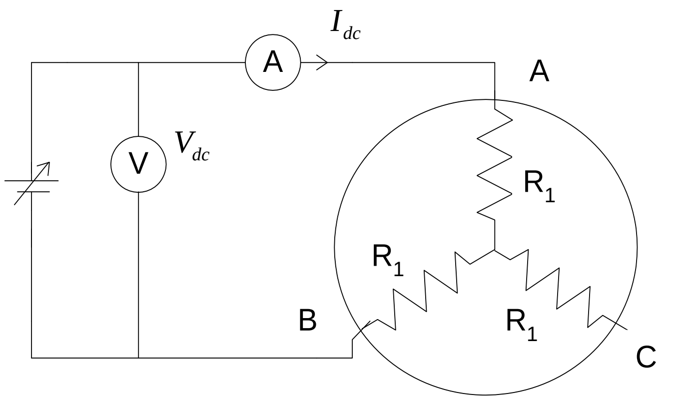

Figure 4. DC test for the determination of the stator resistance

PROCEDURE

NO LOAD TEST

1. Connect the 3-phase induction motor to the 3-phase supply as shown in figure 5. The rated voltage is V_0.
2. Measure the line currents I_a, I_b, and I_c and the wattmeter power W_1 and W_2 $\left(\frac{W_1 + W_2}{3} = P_0 \text{ and } I_0 = \frac{I_a + I_b + I_c}{3}\right)$.
3. Calculate R_0, X_0, Z_0, and φ_0 from equations (1)–(4).

BLOCKED-ROTOR TEST

1. Connect the 3-phase induction motor as shown in figure 6. Make sure to keep the applied voltage zero at starting.
2. Increase the applied voltage so that the rated current flows through the stator winding $V = V_S$.
3. Measure I_a, I_b, and I_c $\left(I_S = \frac{I_a + I_b + I_c}{3}\right)$ and the power W_1 and W_2 $\left(P_S = \frac{W_1 + W_2}{3}\right)$.
4. Apply equations 6–14 to calculate the parameters X_{l1}, X_{l2}, R'_2, and X_M.

DC TEST

By connecting the 3 phase induction motor as shown in figure 4, apply a DC voltage from 0 to 20 volts in steps of 4 volts. Record I_{dc} and V_{dc} and calculate R_1.

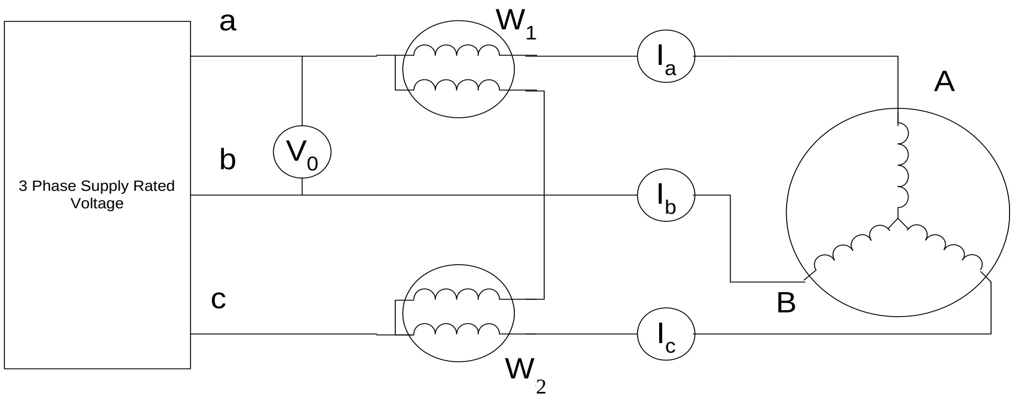

Figure 5. Schematic diagram for the no load test

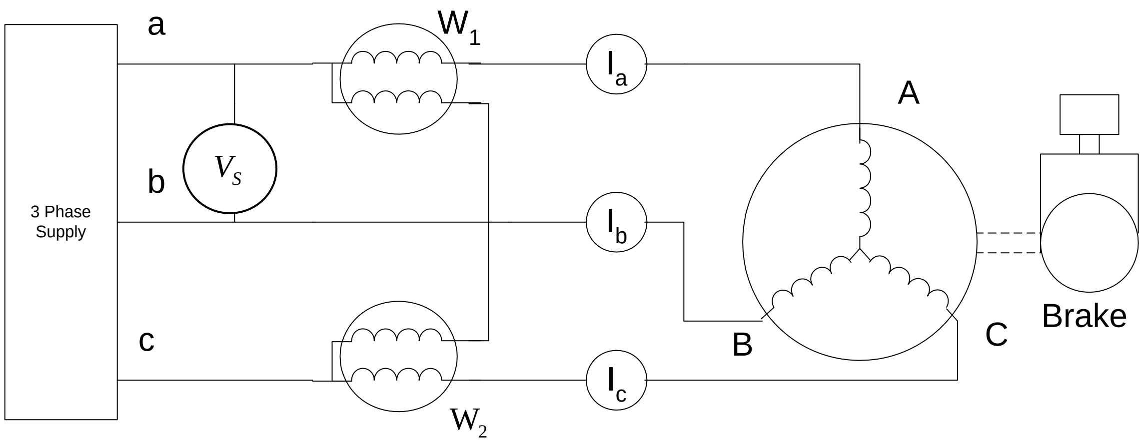

Figure 6. Schematic diagram for the blocked-rotor test