

EXPERIMENT NO. 4

Objective

To perform no-load, blocked rotor and load tests on 1-phase capacitor start- capacitor run induction motor and determine:

- (a) The parameters for the equivalent circuit.
- (b) Compute the performance of motor from the parameters and compare with experimental results.

Theory

1-phase induction motors are constructed much the same way as poly-phase induction motors except that their stators have single-phase-winding-and the rotor is normally a squirrel cage rotor. The poly-phase motors are self starting, while 1-phase motors are not, since its torque, when at rest is zero. In order to start 1-phase induction motor some means are required. The various types of 1-phase induction motors are:

- | | |
|-----------------|---|
| (a) Split phase | (b) Capacitor motor (capacitor start and capacitor run) |
| (c) Shaded pole | (d) Repulsion start |

There are two theories for the analysis of 1-phase induction motor, i.e.

- (1) Cross field theory, and
- (2) Revolving field theory.

Based upon revolving field theory, the equivalent circuit of a 1-phase induction motor with only main winding effective is shown in Figs. 4.1 and 4.2, where,

R_1 = Main winding effective resistance

X_1 = Main winding leakage reactance

Z_f = Rotor impedance with respect to the forward rotating field referred to stator

$$= R_{2f} + jX_{2f}$$

Z_b = Rotor impedance with response of the backward rotating field referred to stator

$$= R_{2b} + jX_{2b}$$

(It is assumed that $R_{2f} = R_{2b} = 0.5 R_2$, $X_{2f} = X_{2b} = 0.5 X_2$)

Y_f = Admittance representing excitation characteristics for the forward field

$$= G_f + jB_f$$

Y_b = Admittance representing the excitation characteristics for the backward field

$$= G_b + jB_b$$

s = Fractional slip with respect to forward field.

In no-load test the motor is run at rated voltage and frequency without applying any mechanical load. The auxiliary winding is disconnected through centrifugal switch as soon as the motor picks up approximately 60% of its rated speed. The input current I_o , voltage E_o , and

input power P_o are recorded.

Under no-load condition, s is very small, R_{2f}/s becomes very large and the equivalent circuit reduces to that shown in Fig.4.3.

In blocked rotor test, a reduced voltage is applied to main winding only, disconnecting the auxiliary winding through autotransformer such that a full rated current is flowing in the main winding. The reduced voltage applied E_s , the rated input current I_s and the input power P_s are recorded.

At rotor standstill, s is unity and the equivalent circuit takes the form shown in Fig.4.4. Just after the blocked rotor test, D.C. resistance of main winding $R_{1,dc}$ is measured to get the value at operating temperature.

Computation of parameters from the test data

As pointed out earlier, under no-load conditions, **impedance of the load branch in the equivalent circuit for forward field is very high (slip small), and may be considered infinite**. Further, the voltage across backward field load branch under no-load conditions is so low that the exciting branch for the backward field may be neglected, i.e. admittance of the exciting branch for backward field is assumed to be zero. The equivalent circuit of Fig.4.1 and 4.2 then reduces to the form shown in Fig.4.3.

The total no-load power input is used up as stator copper loss, $I_o^2 R_1$, backward field resistance copper loss $I_o^2 R_{2b}/2$, forward field excitation (iron) loss and backward field excitation loss (see discussion of this experiment). Under no-load conditions, the magnitude of the backward rotating field is very small, and therefore the backward iron loss may be neglected.

$$\text{Forward field iron loss} = P_{if} = P_o - I_o^2 R_1 - I_o^2 R_{2b}/2$$

$$\begin{aligned}\text{Voltage across the forward exciting circuit} &= V_f \\ &= E_o - I_o \{R_1 + jX_1 + jX_{2b} + (R_{2b}/2)\}\end{aligned}$$

$$\text{Therefore, Exciting circuit admittance, } Y_f = I_o/V_f$$

$$\text{Exciting circuit conductance } G_f = P_{if}/V_f^2$$

$$\text{Exciting circuit susceptance } B_f = \sqrt{Y_f^2 - G_f^2}$$

$$\text{Also, } B_b = B_f, G_b = G_f$$

Thus, all the parameters of the equivalent circuit pertaining to running condition (no-load) are known.

If Z_{sc} is equivalent impedance of the machine during blocked rotor test, $Z_{sc} = E_s/I_s$.

Also if,

$$Z_{sc} = R_{sc} + jX_{sc}$$

$$\text{Then, } R_{sc} = P_s/I_s^2$$

From these relationships, R_{sc} and X_{sc} may be obtained.

As the blocked rotor test is performed at a reduced voltage, the exciting current and core loss during this test are very small and may be neglected. In terms of equivalent circuit, this assumption means that excitation branch admittance is zero. Further, at $s=1$, frequency of the currents on account of both the forward field and backward field are same.

Under this condition, therefore, $R_{2f}=R_{2b}=R_{2e}$ (say), the equivalent circuit of Figs. 4.1 and 4.2 then takes the form shown in Fig.4.4.

If X_2 is the total rotor reactance ($=X_{2f}+X_{2b}$) then $X_1+X_2 = X_{se}$. It is not possible to separate X_1 , X_2 , but it is customary to consider $X_1=X_2=X_{se}/2$. Under blocked rotor condition, it is easy to visualize that $X_{2f}=X_{2b}$

$$X_{2f}=X_{2b}=X_2/2$$

The effective value of main winding resistance at line frequency is usually 1.1 to 1.3 times the d.c. value, the actual ratio depending upon conductor configuration etc..

Thus

$$R_I \approx (1.1 \text{ to } 1.3) R_{1dc}$$

It is seen from Fig.4.4 that

$$R_{sc}=R_I+2R_{2e}$$

where,

$$R_{2e}=(R_{sc}-R_I)/2$$

R_{2e} being the effective rotor resistance at line frequency.

Calculation of Parameters

Under normal running conditions, the forward field-slip is small, and therefore the rotor resistance for this field will be nearly the dc resistance, i.e. R_{2e} divided by a suitable factor to reduce it to its dc value. The factor has a value in the range 1.2 to 1.4 (say 1.3).

Therefore,

$$R_{2f}=R_{2dc}=R_{2e}/k$$

where,

$$1.2 < k < 1.4.$$

With respect to the backward field, the frequency of the rotor currents under running conditions is approximately twice the line frequency. Effective rotor resistance with respect to the backward field at this high frequency is generally 1.6 to 1.8 times R_{2dc} . Therefore, $R_{2b}=1.6$ to $1.8R_{2dc}$, say $1.7R_{2dc}$.

Thus, from known values of R_I , blocked-rotor-data and suitable choice of factors for converting effective resistance into d.c. resistance and vice versa, R_{2f} , R_{2b} , X_{2f} , X_{2b} and X_I are obtained.

Laboratory Work

1. Note down the specification of the machine under test.
2. Draw the circuit diagram as shown in Fig.4.5A, 4.5B and 4.7 for no-load, blocked-rotor and load test respectively and get it approved by lab instructor.
3. Make the connections as shown by the dotted lines and get it checked by the lab instructor for both no-load (use LPF wattmeter) and blocked rotor test (use UPF wattmeter) separately.

No load test:

4. Connect the auxiliary winding of the motor by switching on the MCB provided on the motor base.
5. Apply the rated voltage to the induction motor having both main and auxiliary windings connected together through 1-phase autotransformer. The auxiliary winding will be disconnected automatically by the centrifugal switch as soon as the motor attains about 60% of rated speed.
6. Record the applied rated voltage E_o , no-load current I_o and input power P_o .
7. Increase the applied voltage by 10% and record no-load current and power input.
8. Reduce the applied voltage in suitable equal steps and record the current and power input for several values of the applied voltage but not less than 180V.
9. Stop the motor.

Blocked rotor test:

10. Disconnect the auxiliary winding by switching off the MCB provided at the motor base.
11. Slowly increase the voltage to the main winding starting from 0V, with the autotransformer such that the rated full load current flows in the stator main winding. Do not hold this condition for long time otherwise; it will burn down the main winding of motor.
12. Record the applied voltage E_s , the rated input full load current I_s and power P_s .
13. After performing the blocked rotor test, measure the D.C. resistance of the stator, R_{ldc} .

Load test:

14. Now work on the motor which is coupled to the D.C shunt generator. Make the connections as shown in Fig. 4.7.

15. Switch on the cooling fan of the DC generator.
16. Apply rated voltage to the induction motor and run the generator under no-load condition.
17. Note down the readings of input power, input current, output voltage, output current and speed of the motor.
18. Switch on the dc supply of field circuit of dc generator and set output voltage 180V of dc generator by varying the rheostat and keep it constant throughout the experiment.
19. Now switch on the load box switches step by step up to when the rated current flows in the induction motor. Note down all the meter readings.
20. Repeat the steps for reduced input voltage (**90% of rated value**). Tabulate your readings as follows.

Applied voltage	Input power	Input current	DC-Generator current	DC-Generator voltage	Speed

Report

1. (a) Plot no load current power input as a function of applied voltage in case of no-load test and obtain from there the no load current, I_a , and power input P_o corresponding to the rated voltage.
 (b) Extrapolate the curve of P_o up to zero voltage to obtain the friction and windage loss as shown in Fig.4.6.
2. Compute the parameters of the equivalent circuit.
3. From the equivalent circuit, compute input current, input power, efficiency and torque when the motor is running at the rated voltage with slip of 5%.
4. From load test data, plot Torque vs. Slip characteristics for different voltage levels

Discussion

The equivalent circuit derived in this experiment is based on number of approximations. R_{2f} and R_{2b} are the effective values of resistances, which change with slip. However, for normal range of running speeds ($s=1-5\%$), these effective values may be assumed to remain constant. The leakage reactance is assumed to be equally divided between the stator and rotor, whereas actually it may not be so. The factor for converting effective values of resistance into d.c. values and vice-versa are arbitrary and cannot be easily determined.

By far, the most important assumption is that the friction and windage losses, which are mechanical, are combined with the other losses in calculating the loss conductances, G_f and

G_b . For a more accurate analysis, friction and windage loss should be subtracted from the mechanical power developed, and should not be included along with excitation losses.

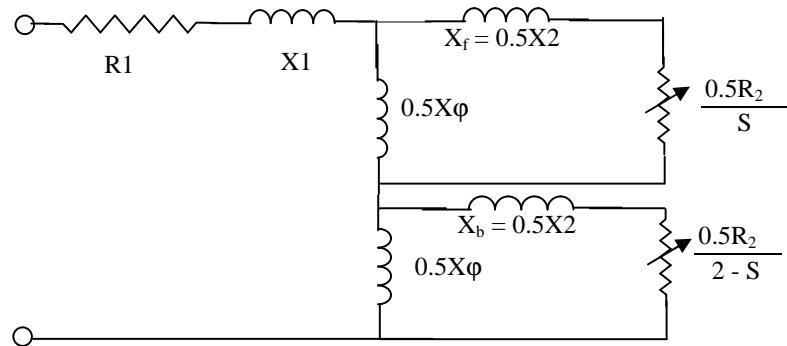


FIG. 4.1 Equivalent circuit of a 1-phase Induction motor

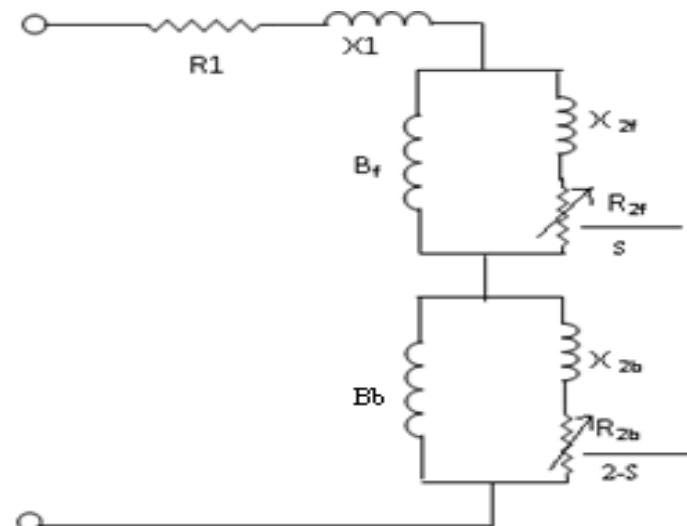


FIG. 4.2 Equivalent circuit of 1-phase Induction motor (alternate representation)

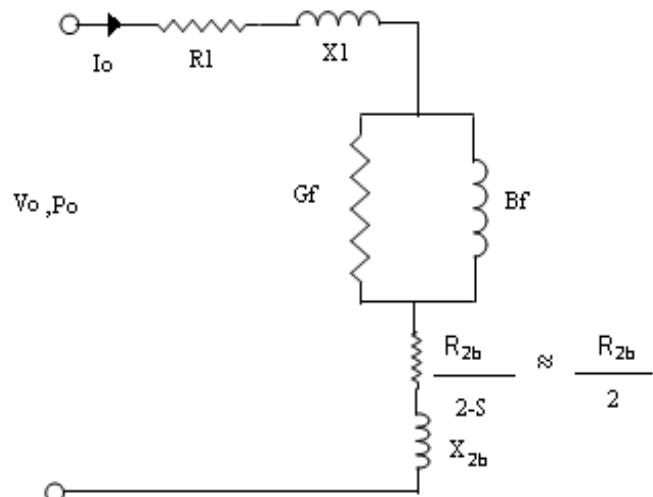


FIG. 4.3 Simplified equivalent circuit under no-load

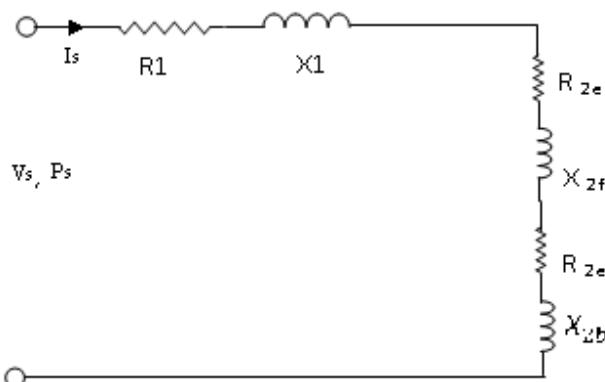
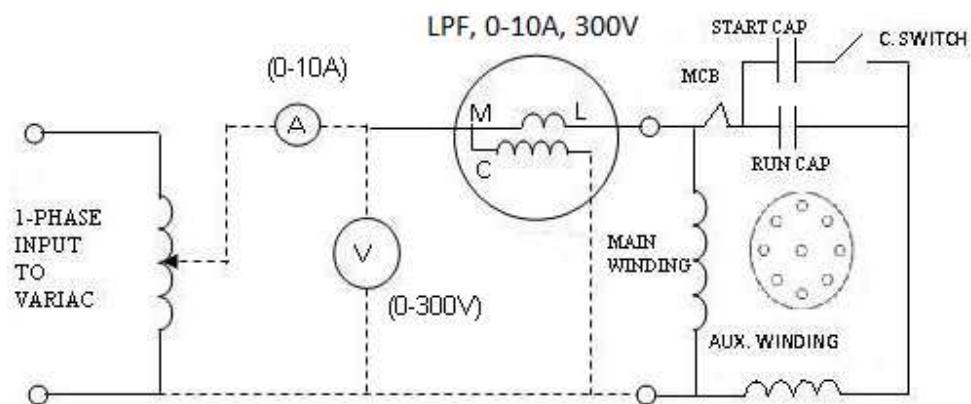
FIG. 4.4 Simplified equivalent circuit during blocked rotor test $S \approx 1$ 

FIG.4.5A Connection diagram for No-Load Test

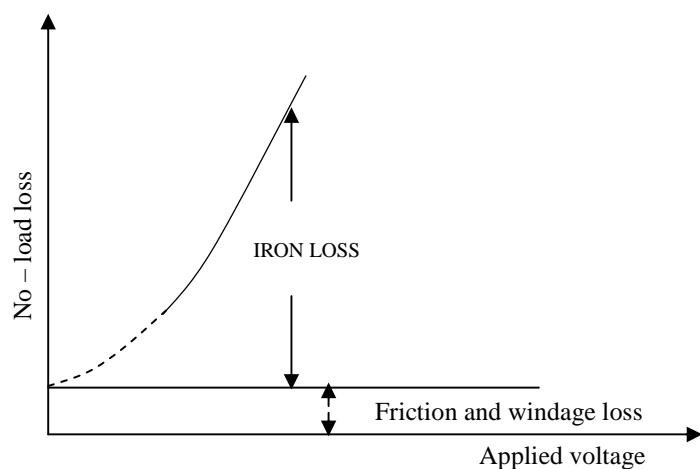
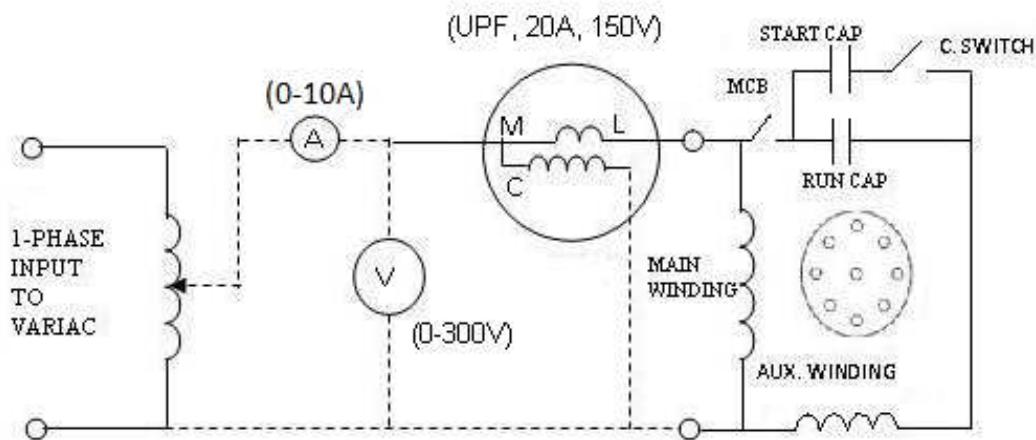


FIG. 4.6 Determination of friction and windage loss

Note: The low power factor wattmeter required the additional single phase ac supply for working. The connection cord is provided for the purpose

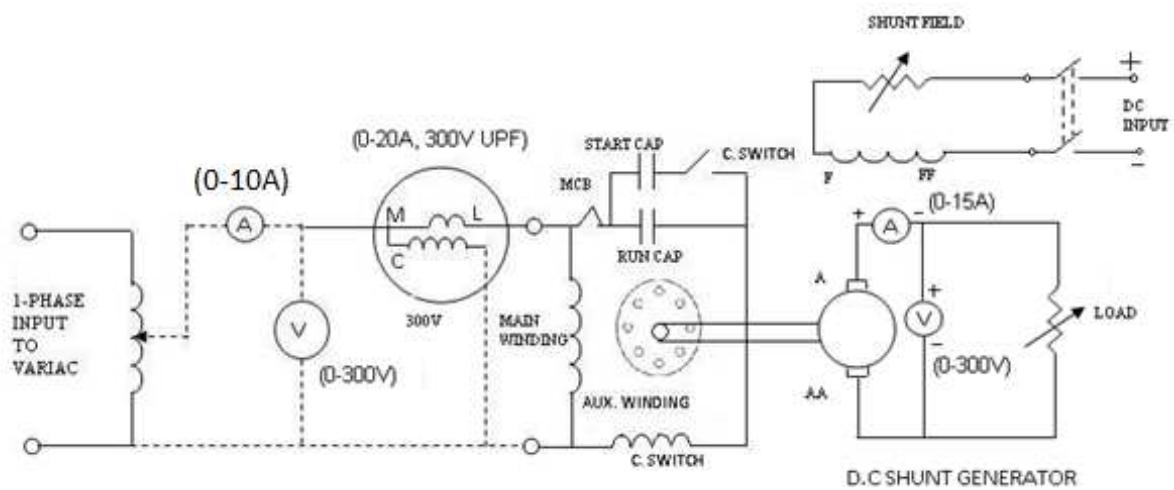


FIG. 4.7 Connection diagram for Load Test