Ex-7-326

EXPERIMENT NO. 13

STARTING CHARACTERISTICS OF SQUIRREL-CAGE INDUCTION MOTORS

PURPOSE:

To determine the starting torque of a squirrel-cage induction motor.

BRIEFING:

Three-phase voltage applied to the stator produces a revolving field in the air gap between the stator and the rotor. This field starts revolving the instant that the switch is closed. At that instant, however, the rotor is not moving.

As the magnetic field sweeps around, its flux lines are cut by the squirrel-cage rotor bars. This induces a voltage into the bars, which results in rotor current flow because the bars form a complete circuit.

At the instant of start, the frequency of the induced rotor current is at maximum--equal to the frequency of the applied power. That makes the rotor's inductive reactance maximum, too ($X_L = 2\pi\sqrt{\ } fL$). The large inductive reactance of the rotor produces a poor rotor power factor. Since, at the instant of start, the rotor is like the secondary of a transformer, the result is an overall low starting power factor for the motor.

Induced rotor voltage is also maximum at the instant of start. That's when there is the greatest relative motion between the revolving field and the rotor bars. Beside being inversely proportional to rotor impedance, rotor current is directly proportional to rotor voltage. Transformer action causes this rotor current to be reflected in the stator windings. Starting current is quite high, several times full load current.

Finally, consider the starting torque. At all times, torque is proportional to the strength of the stator field, the strength of the rotor field (as expressed in terms of rotor current) and phase angle between the two fields. The equation is:

$$T = K\phi \, I_R \cos\theta$$

As it turns out the expression, $\cos\theta$ is also the rotor power factor. Therefore, even though starting current is high, starting torque is not high because of the poor power factor at start.

There is another thing you can figure out by studying the above equation. The stator field strength, ϕ, is proportional to applied voltage. Also, the rotor current, I_R, is proportional to applied voltage. Starting torque, therefore, is proportional to the applied voltage squared.

$$T_{ST} = K' (V_A)^2$$

What this means is that if you cut the applied voltage in half (V/2), the torque will be only one fourth ($(V/2)^2 = V/4$).

Knowing this allows us to look the rotor and measure starting torque at a reduced voltage; then compute what it would be at full voltage. If full voltage were applied, the high starting current would trip the circuit breakers before we could get a reading.

PERFORMANCE OBJECTIVES:

Upon successful completion of this experiment, the student will be able to :

1. Perform a locked rotor test on a squirrel-cage induction motor.

2. Describe the starting characteristics of a squirrel-cage induction motor and explain the reason for those characteristics.

MACHINES REQUIRED:

IM-100 Three Phase Squirrel-Cage Induction Motor
DYN-100-DM Electrodynamometer

POWER REQUIRED:

0 - 240 Variable 3-phase AC

METERS REQUIRED:

0 - 8 AMP AC Ammeter
Two 0 - 600 Watt AC Wattmeters
0 - 150 Volt AC Voltmeter

ADDITIONAL MATERIAL REQUIRED:

MGB-100-DG Bedplate

PROGRAM PLAN:

Step 1. Place the two machines on the bedplate. Motor on the left; dynamometer on the right. Couple and clamp the machines securely. Install guards.

Step 2. Connect the Induction Motor, IM-100, as shown in Figure 13-1. Be careful to observe polarity when connecting wattmeters. The "two-wattmeter method" of measuring total power is being used.

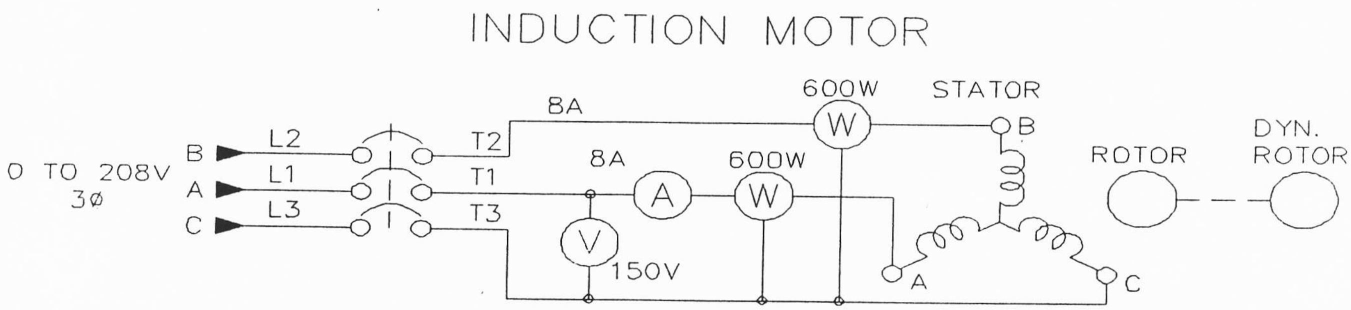

Figure 13-1

Step 3. Install the rotor locking device securely on the dynamometer. Zero the dynamometer scale by positioning the weight at the rear.

Step 4. Have someone check your connections to be sure they are correct. Then turn voltage control knob fully counterclockwise to its zero output position. Turn ON the main AC and the 0-240V AC circuit breakers.

Step 5. This step is to be performed as quickly as possible. With the motor circuit breaker off, turn the voltage control knob clockwise until the voltmeter reads 108 volts. (NOTE: when the motor is turned on, the voltage will drop to 104 volts. This is the voltage at which readings are to be taken.) Turn the motor ON and quickly read line amps, torque, wattmeter #1, and wattmeter #2. Turn the motor OFF and record these readings in TABLE 13-1 of TEST RESULTS.

Step 6. Repeat Step 5 two additional times. Allow two minutes before tests.

Step 7. Average the three tests and record the average values of current, torque, and power in TABLE 13-1.

Step 8. Turn OFF all circuit breakers. Disconnect all leads.

TEST RESULTS:

	LINE VOLTS	LINE AMPS	TORQUE	WM #1	WM #2	TOTAL WATTS
TEST 1	104					
TEST 2	104					
TEST 3	104					
AVERAGE	104					

TABLE 13-1

	VOLTS	AMPS	TORQUE
FULL VOLTAGE STARTING	208		
FULL LOAD RUNNING	X	2.4	195
STARTING/RUNNING %	X		

TABLE 13-2

DE-BRIEFING:

1. Full voltage is 208 volts. Your tests were run at one-half full voltage (104 volts). Starting current would therefore be twice the value you measured. Compute full voltage starting current and record in TABLE 13-2.

2. Torque is proportional to applied voltage squared. Therefore, full voltage starting torque would be four (4) times (2^2) the torque you measured at one-half voltage. Compute full voltage starting torque and record in TABLE 13-2.

3. Compute the ratio of full load starting current (which you computed in #1) to the rated full load running current (2.4 amps).

4. The total apparent power is computed from the equation:

$$Ps = 1.73\ E\ I \text{ volt-amperes}$$

Compute the reduced voltage starting apparent power using the current read in step 5.

P_S = ________________

5. The true power (P) at reduced voltage is the sum of the two-wattmeter readings. The power factor is the ratio of true power to apparent power--P.F. = P/P_S. Compute the power factor (cos ϕ).

P.F.= ______________.

In the trig tables find the angle (whose cosine equals the P.F. computed above) by which rotor current lags rotor voltage.

ϕ = __________ °.

QUICK QUIZ:

1. Starting current is:

   a) greater than full load current.

   b) less than full load current

   c) the same as full load current.

2. Full load running torque is:

   a) greater than starting torque.

   b) less than starting torque.

   c) the same as starting torque.

3. Each amp of starting current provides:

   a) the same torque as each amp of running current.

   b) more torque than each amp of running current.

   c) less torque than each amp of running current.

4. You would get more in-oz of starting torque from each amp of starting current if:

a) there were more inductive reactance in the rotor.

b) there were more resistance in the rotor.

c) the rotor bars did not form a complete circuit.

5. At the instant of start, an induction motor has:

a) a leading phase angle.

b) a good power factor, small lagging phase angle.

c) a poor power factor, large lagging phase angle.

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Discussion Points for Lab 7

20 pts

1.) Explain how the induced voltage in the rotor of an induction motor changes as the rotor speed changes.

2.) Show a per-phase schematic model of an induction motor and explain why the rotor current magnitude stays almost constant while the rotor power factor changes.

3.) Explain the relationship between stator terminal voltage and motor tourque.

4.) Draw the connections for the 2-Wattmeter method of measuring active power. How is power factor found from the power measurements? Use both words and equations