# Experiment 5

### The Wound-Rotor Induction Motor – Part III

#### OBJECTIVE

- To observe the characteristics of the wound-rotor induction motor at no-load and full-load.
- To observe speed control using an external variable resistance.

#### DISCUSSION

The three ends of the three-phase rotor windings are brought out to three slip rings mounted on the rotor shaft. The brushes bearing on the slip rings play an important role in realizing maximum advantage from the wound-rotor motor. By connecting the brushes through rheostats, it becomes possible to develop a higher starting torque than is possible with a squirrel-cage motor. On starting, the full resistance of the rheostats is maintained in the rotor circuit, thus providing the very maximum starting torque.

As the motor approaches normal operating speed, the rheostat resistance is gradually reduced until it is out of the circuit entirely at full speed. Although the starting torque of the wound-rotor motor is higher, it is not as efficient as the squirrel cage motor at full speed, because the resistance of the rotor windings is always more than that of a squirrel cage motor.

A special feature of the wound-rotor motor is its variable speed capability. By varying the rheostat resistance, it is possible to vary the percentage of slip and thus, vary the motor speed. In such cases, below full speed operation means the motor is running at reduced efficiency and mechanical output power. In addition, because of a high rotor resistance, the motor is made more susceptible to variation in speed as the load changes.

#### EQUIPMENT REQUIRED

Refer to the Equipment Utilization Chart, in Appendix A of this manual, to obtain the list of equipment required to perform this exercise.

### PROCEDURE

#### CAUTION!

High voltages are present in this Experiment! Do not make any connections with the power on! The power should be turned off after completing each individual measurement!

- □ 1. a. Examine the construction of the Three-Phase Rheostat, paying particular attention to the circuit schematic diagramed on the face of the module.
  - b. Note that the arms of the three rheostats are separately brought out to terminals 1, 2 and 3. The remaining ends of the rheostats are wired together internally and brought out to the N terminal.
  - c. Note that the three rheostats are ganged together and that their individual resistances cabe varied simultaneously by turning the single control knob.
  - d. When the control knob is fully ccw the resistance of each rheostat is 0  $\Omega$ . When the control knob is fully cw the resistance of each rheostat is 16  $\Omega$ .
- □ 2. Using your Three-Phase Wound-Rotor Induction Motor, Electrodynamometer, Single-Phase Wattmeter, Three-Phase Rheostat, Power Supply, AC Ammeter and AC Voltmeter, connect the circuit shown in Figure 5-1. Do not couple the motor to the electrodynamometer at this time!
- □ 3. a. Set the speed control rheostat knob at its full ccw position for zero resistance.
  - b. Turn on the power supply and adjust  $E_1$  to 208 V ac. The motor should be running.
  - c. Measure and record in Table 5-1, the three line currents, the two wattmeter indications (remember, to observe the polarities) and the motor speed.
  - d. Return the voltage to zero and turn off the power supply.



Figure 5-1.

- 4. a. Couple the motor to the electrodynamometer with the timing belt.
  - b. Set the dynamometer control knob at its full ccw position.
  - c. Repeat procedures 3 for each of the torques listed in Table 5-1, maintaining the input voltage at 208 V ac.
  - d. Return the voltage to zero and turn off the power supply.

TORQUE (N·m)	I₁ (amps)	Ι <sub>2</sub> (amps)	I₃ (amps)	W₁ (watts)	W <sub>2</sub> (watts)	SPEED (r/min)
0						
0.3						
0.6						
0.9						
1.2						

TORQUE (lbf-in)	ا, (amps)	اہ (amps)	I, (amps)	W, (watts)	W, (watts)	SPEED (r/min)
0						
3						
6						
9						
12						

Table 5-1.

- 5. a. Set the speed control rheostat knob at its full cw position for maximum resistance.
  - b. Uncouple the motor from the electrodynamometer.
- $\hfill\square$  6. a. Turn on the power supply and adjust  $E_1$  to 208 V ac. The motor should be running.
  - b. Measure and record in Table 5-2, the three line currents, the two wattmeter indications and the motor speed.
  - c. Return the voltage to zero and turn off the power supply.

TORQUE (N∙m)	l <sub>₁</sub> (amps)	l₂ (amps)	l₃ (amps)	W₁ (watts)	W₂ (watts)	SPEED (r/min)
0						
0.3						
0.6						
0.9						
1.2						

Table 5-2.

TORQUE (lbf-in)	ا, (amps)	ا (amps)	I, (amps)	W, (watts)	W, (watts)	SPEED (r/min)
0						
3						
6						
9						
12						

Table 5-2.

- 7. a. Couple the motor to the electrodynamometer with the timing belt.
  - b. Set the dynamometer control knob at its full ccw position.
  - c. Repeat procedure 6 for each of the torques listed in Table 5-2, maintaining the input voltage at 208 V ac.
  - d. With a developed torque of 0.9 N·m [9 lbf·in], rotate the speed control rheostat knob from full cw to full ccw.
  - e. Does the motor speed change?

□ Yes □ No

f. Does the developed torque change?

□ Yes □ No

- g. Return the voltage to zero and turn off the poser supply.
- $\square$  8. a. Connect the circuit shown in Figure 5-2. Note that the fixed 3 $\phi$  output of the power supply, terminals 1, 2 and 3 are now being used.
  - b. Set the dynamometer control knob at its full cw position (to provide a maximum starting load for the motor).
  - c. Set the speed control rheostat knob at its full cw position (to provide maximum resistance).





 $\Box$  9. a. Turn on the power supply and quickly measure  $E_1$ ,  $I_1$ ,  $I_2$  and the developed starting torque. Turn off the power supply.

 $I_1 = \_$  A ac,  $I_2 = \_$  A ac  $E_1 = \_$  V ac, Torque = \_ N·m [lbf·in]

b. Calculate the apparent power to the motor at starting torque.

Apparent power = \_\_\_\_\_ VA

### **REVIEW QUESTIONS**

- 1. Using the results of Table 5-1, calculate the no-load characteristics of the wound-rotor motor.
  - a) average current

\_\_\_\_\_ = \_\_\_\_\_ A ac

b)	apparent power		
		=	VA
c)	active power		
		=	W
d)	reactive power		
		=	var
e)	) power factor		
		=	
2. U th	sing the results of Table 5-1, calculate the 0.9 ie wound-rotor motor (with 0 $\Omega$ external rotor	9 N⋅m <mark>[9 lbf⋅in]</mark> char resistance).	acteristics of
a)	average current		
		=	A ac
b)	apparent power		
		=	VA
c)	active power		
		=	W

	d)	reactive power		
			=	var
	e)	power factor		
			=	
	f)	mechanical output power		
			=	W <mark>[hp]</mark>
	g)	efficiency		
			=	%
3.	Usi the	ing the results of Table 5-2, calculate wound-rotor motor (with 16 $\Omega$ exter	the 0.9 N·m <mark>[9 lbf·in]</mark> cha nal rotor resistance).	aracteristics of
	a)	average current		
			=	A ac
	b)	apparent power		
			=	VA
	c)	active power		
			=	W

d)	reactive power		
		=	V
e)	power factor		
		=	
f)	mechanical output power		
		=	W <mark>[h</mark> j
g)	efficiency		
		_ =	
Usi cale	ing the results of procedure 9 and Tabl culations (use the 0.9 N·m [9 lbf·in] charac	e 5-2, make the teristics for the fu	following rat Il-load values
a)	starting current to full-load current		
		=	A a
b)	starting torque to full-load torque		
		=	N·m <mark>[lbf∙i</mark> ı
c)	full load current to no-load current		
		_	A a

5. The efficiency of the motor is much lower when the external resistance is in the motor circuit. Explain.

6. The power factor improves with loading. Explain.