

LABORATORY SESSION 9 WOUND ROTOR INDUCTION MOTOR CHARACTERISTICS



CAUTION: High voltages are present in this Laboratory Experiment! Do not make any connections with the power on! The power must be turned off before the circuit is modified.

PURPOSE

The purpose of this experiment is to obtain the performance characteristics of a wound rotor induction motor and to show that the wound rotor motor can be used as a power source of variable voltage and frequency.

DISCUSSION

For the discussion on the principle operation of induction motor, its equivalent circuit and formulas refer to Experiment # 8 on the squirrel cage induction motor.

A very small percentage of induction motors have a wound rotor. A wound rotor has a complete set of three-phase windings that are mirror images of the windings on the stator. The three phases of the rotor windings are usually Y-connected, and the ends of the three rotor wires are tied to slip rings on the rotor's shaft on which the brushes rest. The brushes can then be connected to a three-phase variable resistor and the resistance of the rotor winding can be externally controlled. This variable resistor controls the torque-speed characteristics of the motor. As the rotor circuit resistance is increased, the pullout speed of the rotor decreases, but the maximum torque remains constant. The external resistance can be adjusted to make the maximum torque occur at starting conditions. This external resistance can be decreased as the motor speeds up, making the maximum torque available over the whole accelerating range. Induction machines with wound rotors are used for special applications, but because they are less efficient at higher slips, they are being replaced by squirrel-cage induction motor with variable-speed drives.

Three-phase wound rotor induction machines can be used to furnish, at their slip-ring terminals, a three-phase source of variable voltage and frequency. For this application, the induction machine is connected to a normal voltage and frequency supply and is driven by a variable-speed motor as shown in Figure 9.1. The voltage induced in the rotor, and its frequency, are directly proportional to the operating slip.

$$E_r = sE_2 \quad (9.1)$$

$$f_r = sf_s \quad (9.2)$$

Where E_2 is the rotor emf when motor is at standstill, and f_s is the stator frequency. When the rotor is running in the same direction as its synchronously rotating magnetic field, the slip is

$$s = \frac{n_s - n_r}{n_s} \quad (9.3)$$

For small slip the rotor frequency is low. If the direction of the synchronously rotating magnetic field is opposite to the rotor direction, the slip is

$$s = \frac{-n_s - n_r}{-n_s} = 1 + \frac{n_r}{n_s} \quad (9.4)$$

The slip will be greater than unity, the rotor voltage will be larger and its frequency will be larger than that of the stator. The slip rings of the wound rotor can thus become a power source of variable voltage and frequency.

PROCEDURE

1. Induction Frequency Changer

Connect the dynamometer as a shunt motor. Connect the induction motor stator terminals to the three-phase supply and the ScopeMeter to two of the rotor slip ring terminals as shown in Figure 9.1.

(a) Turn on the three-phase ac power supply. With the motor at standstill (dc power off) measure the standstill rotor emf

$$E_2 = \underline{\hspace{2cm}}$$

(b) With the dc motor starter resistance in and the field rheostat set for minimum value, start the dc motor. Adjust the dc motor speed by means of the field rheostat at a low value, say 1400 rpm and record rotor voltage and frequency in Table I. Adjust the dc motor speed to higher values, around 1500, 1600, 1800, 1900 rpm and record the corresponding rotor voltage in Table I.

(c) Turn the power off, and interchange any two of the three-phase leads to the induction motor stator. Make sure the dc motor starter is in and the field rheostat is at its minimum value. Start the dc motor; turn on the three-phase power supply. Repeat the measurements in part (b) and record in Table I.

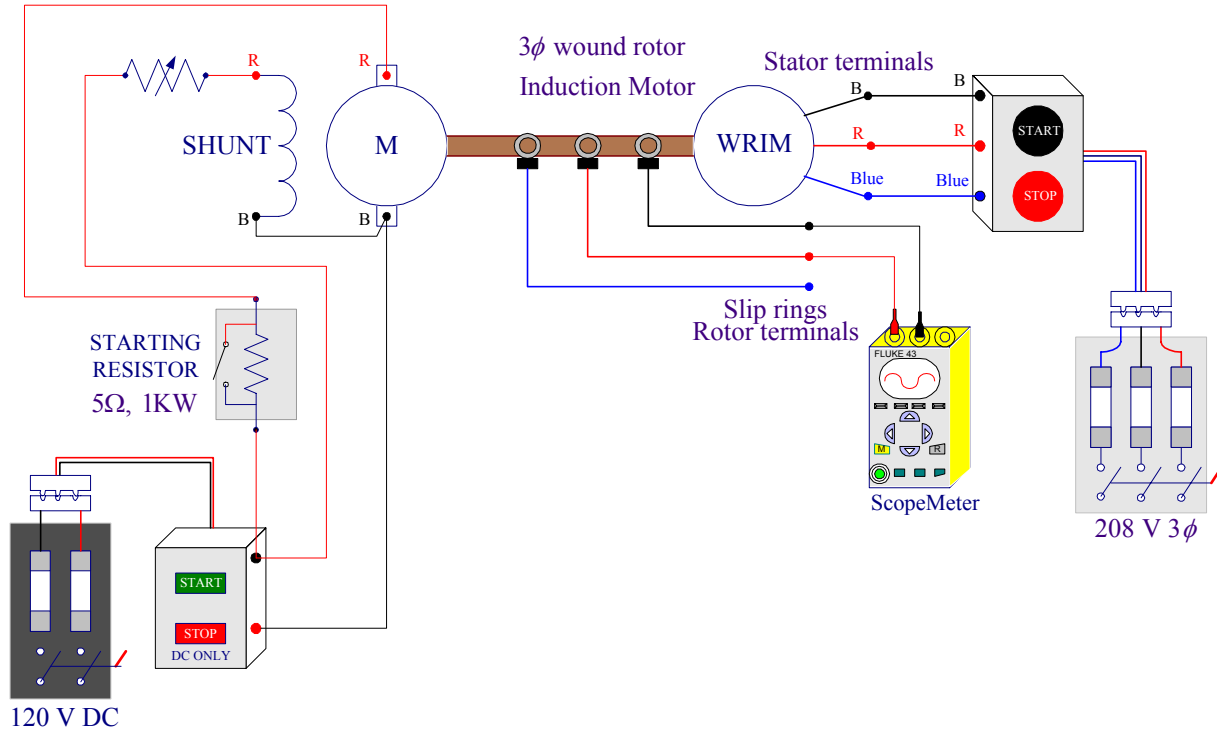


Figure 9.1 Induction frequency changer

Table I

Direction of rotating magnetic field	Measured Data			Calculated Data		
	Speed RPM	E_r Volt	f_r Hz	Slip s	$E_r = s E_2$ Volt	$f_r = s f_s$ Hz
Same as the rotor direction						
Opposite the rotor direction						

2. PERFORMANCE CHARACTERISTICS

Check out the Fluke Power Quality Analyzer from the Technical Support Center.

Connect the induction motor to the 208V, three-phase supply as shown in Figure 9.2. Connect the red-shielded test lead (you may use ordinary lead) from the Power Quality Analyzer input 1 to the black terminal of the three-phase supply and a black lead from the COM terminal to the blue terminal of the three-phase supply. This will provide V_{B-Blue} voltage for the wattmeter.

Connect the Current Probe to the meter input 2 and clamp the Current Probe around the lead connecting the supply black terminal to the motor black terminal. Be sure that the arrow marked on the jaw of the Current Probe points toward the direction of current (supply to load). This will provide the current I_b for the wattmeter. The real power recorded with this connection is designated as P_1 . Same meter is to be used to measure P_2 by moving the lead coming from input 1 and the current probe to the red phase and keeping the black test lead (COM) attached to the blue phase. To measure voltage and current open the main menu and select VOLTS/AMPS/HERTZ, and to measure Watt open the main menu and select POWER.

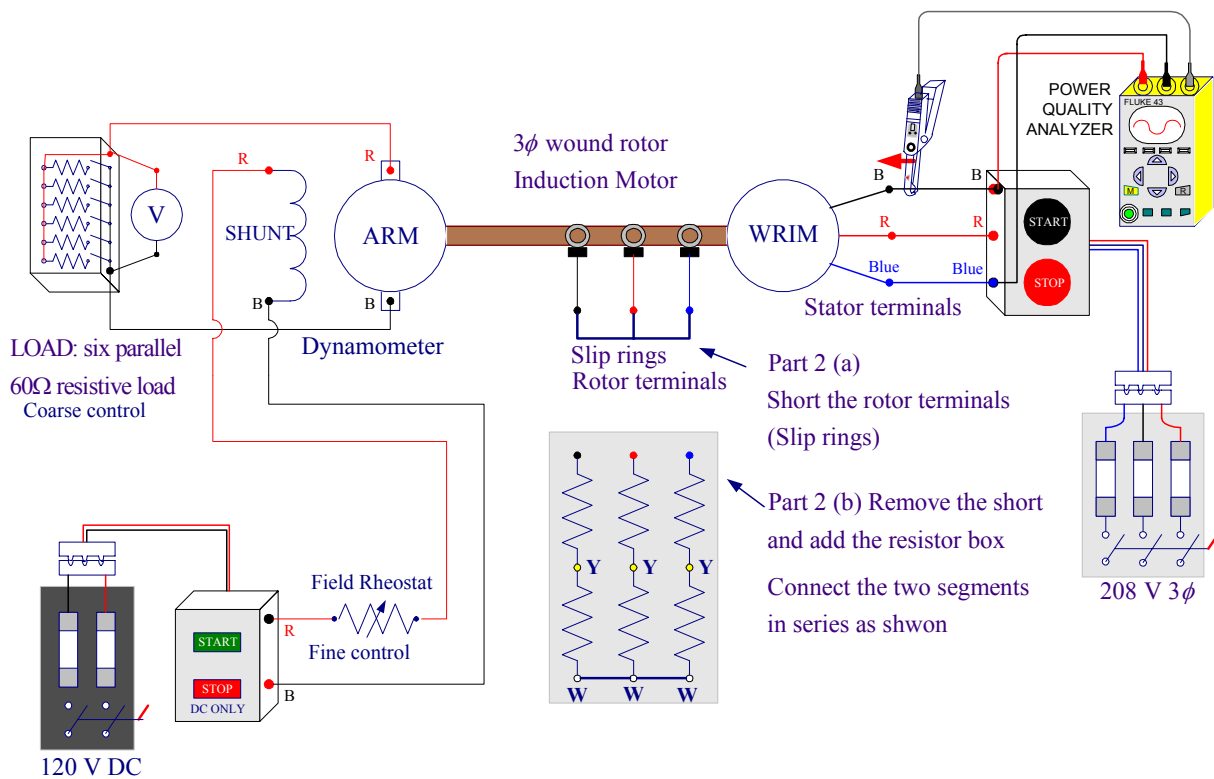


Figure 9.2 Circuit connections for wound rotor induction motor and dynamometer.

The induction motor is to be loaded by means of the dynamometer. Connect the dynamometer as a separately-excited dc generator as shown in Figure 9.2.

(a) No external rotor resistance

Short the rotor terminals (no external rotor resistance). Zero the dynamometer scale. Start the induction motor.

Zero the dynamometer scale. Start the induction motor. With the dynamometer on no-load and its field winding open (dc supply off) record the following data for the motor in Table 1: input line-to-line voltage, stator current I_1 , real power reading P_1 , motor speed and the dynamometer pull. Move the red test lead (Coming from input 1) and the Current Probe to the red phase (keep the black test lead (COM) attached to the blue phase. Be sure that the arrow marked on the jaw of the Current Probe points toward the direction of current (supply to load). This will provide V_{R-Blue} and the current I_{Red} for the wattmeter. Measure the real power and record it in Table I as P_2 .

At no-load, the motor power factor is low, if $\theta > 60^\circ$ according to (8.10), one wattmeter (P_2) will read negative. When the motor power factor is 0.5, ($\theta = 60^\circ$), P_2 will read zero and P_1 will indicate the total power taken by the motor. As the motor is loaded more, its power factor will become greater than 0.5 and both wattmeter readings will be positive.

Using the load resistor for coarse adjustments and the dynamometer field rheostat for fine adjustment, load the motor in step until it draws the full-load current. Repeat the above procedure and at each step record the phase current I_1 , the real power measurements P_1 and P_2 , motor speed and dynamometer pull in Table I. Record the synchronous speed.

Stop the motor, and disconnect it from the 208V. Evaluate the calculated data and enter in Table I.

(b) External resistance added in the rotor circuit

Place the three-phase resistor board in the rotor circuit as shown in Figure 9.2. Start the motor and repeat the above procedure and record the measurements in Table II.

$n_s =$ _____

Stop the motor, and disconnect it from the 208V. Evaluate the calculated data and enter in Table II.

3. Use **ee340lab9** function as explained in the Appendix to check your computed data and obtain the required plots.

REPORT REQUIREMENTS

1. Using (9.3) and (9.4) compute the slip and from (9.1) and (9.2) compute the rotor emf and frequency, record in table I and compare with the measured values. Discuss the application and disadvantages of the induction frequency changer and explain by what means a modern variable frequency supply is obtained these days.
2. Using Equations (8.13)-(8.18), calculate the load torque, power output, power input, slip, power factor and efficiency of the induction motor from measured data at each loading. Show sample calculations.
3. Plot on one graph curves of stator current and torque versus speed. On a second graph, plot curves of power factor and efficiency versus speed. Draw the results with added rotor resistance on same graphs. Explain the theoretical basis for the shape of all the curves. Discuss the effect of adding rotor resistance on the motor characteristics.

Appendix

In MATLAB, from **File/New/M-File**, open the MATLAB Editor. Enter the data for the wound rotor induction motor part 2(a) and (b) in two $n \times 6$ matrix named WRIM1 and WRIM2. Each column represents a variable that must be entered in the order shown below. Use the function named **ee340lab9** as indicated below to obtain the calculated data and the required plots. The function **ee340lab9** has been added to the MATLAB available on the MSOE network. If you have your own MATLAB student version you may download this function to your Laptop.

```
%      V      I1      P1      P2      n      Pull
WRIM1=[
                                           ];

WRIM2=[
                                           ];

ee340lab9(WRIM1, WRIM2)
```