EXPERIMENT MD1: CHARACTERISTICS OF INDUCTION MOTOR

Related course: KIE2009 (Machines and Drives)

OBJECTIVES:
To study the characteristics of induction motor

EQUIPMENT:
Wound rotor induction motor, Control Unit, three-phase external rotor resistor, stopwatch, voltmeter, ammeter, power factor meter, wattmeter, zero-centred ammeter

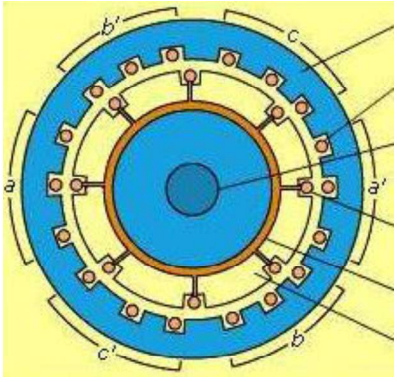
INSTRUCTIONS:
1. Record all your results and observations in a log book / paper.
2. Before the wound rotor induction motor in the circuit is started, make sure that the external rotor resistor is at maximum position (position 1).
3. Do not change the circuit connection without permission from the lab demonstrator or technician.

REFERENCE(S):
Refer to the main references of KIE2009

TESTS:
TEST 1: Starting of induction motor
TEST 2: Direct measurement of slip
TEST 3: Load test

INTRODUCTION:

An induction (asynchronous) motor is an AC electric motor, which the electric current in the rotor is needed to produce torque, is obtained by electromagnetic induction from the magnetic field of the stator winding. An induction motor does not require mechanical commutation, separate-excitation or self-excitation for all or part of the energy transferred from stator to rotor, as in DC and large synchronous motors. An induction motor's rotor can be either wound type or squirrel-cage type.



Three-phase induction motor structure

Three-phase squirrel-cage induction motors are widely used in industrial drives because they are rugged, reliable and economical. Single-phase induction motors are used for smaller loads, such as household appliances. Induction motors are used with variable-frequency drives (VFDs) in variable-speed service. VFDs offer energy savings opportunities for induction motors in variable-torque centrifugal fan, pump and compressor load applications. Squirrel cage induction motors are widely used in fixed-speed and VFD applications. Variable voltage and variable frequency drives are also used in variable-speed service.

The stator of an induction motor consists of poles carrying supply current to induce a magnetic field that penetrates the rotor. To optimize the distribution of the magnetic field, the windings are distributed in slots around the stator, with the magnetic field having the same number of north and south poles. The conductor bars of cage induction motor's rotor are typically skewed to reduce noise.

TEST 1: Starting of induction motor

1. Obtain the ratings/rated values of motor, which are displayed on motor's nameplate and make sure that these limits are not exceeded throughout the experiment.
2. Study and understand the panels for circuit connection. Make sure that you understand the functionalities of all equipment.
3. Make sure that the circuit connection is as shown in Figure 1. Make sure that the external rotor resistor is at position 1.
4. Turn ON the main power supply, the Control Unit, voltmeter and both ammeters. Do not turn ON the wattmeter and power factor meter at this stage.
5. On the Control Unit panel, keep turning the "SET/START VALUE" knob clockwise until it cannot be turned anymore. Once achieved, that represents 0 Nm torque.
6. Start the motor by turning ON the three-phase power supply and adjust the load torque to obtain the required motor speed N as given in Table 1. Starting speed should be 1350 rpm or the maximum speed achievable by the motor. The load torque can be adjusted by slowly turning the knob labelled with "SET/START VALUE" on the Control Unit. Read the load torque T and line current I_{line} (from the ammeter) and complete Table 1. Repeat the experiment for different external rotor resistor position.
7. Adjust the load torque to 1 Nm (using the Control Unit) and maintain it throughout this test. Read the corresponding line current (from the ammeter) and rotor speed (from the Control Unit). Repeat this step for position 1 (maximum) to position 6 (minimum) of the external rotor resistor and complete Table 2.

Table 1

Position of external rotor resistor	Motor speed N (rpm)	1350	1300	1250	1200	1150	1100	1000
1	I_{line} (A)							
	T (Nm)							
3	I_{line} (A)							
	T (Nm)							
5	I_{line} (A)							
	T (Nm)							
6	I_{line} (A)							
	T (Nm)							

* Check the setting of the torque on the Control Unit (x1, x2 or x5) while reading the value. E.g. if x2, multiply the torque reading with 2

Table 2 (Load torque = 1 Nm)

Position of external rotor resistor	1	3	5	6
Motor speed N (rpm)				
Line current I_{line} (A)				

QUESTIONS:

1. Plot the graphs of line current I_{line} vs. rotor speed N and torque T vs. motor speed N using the measured values in Table 1. With respect to positions of external rotor resistor, explain the shapes of the curves and relationships of I_{line} vs. N and T vs. N.
2. From Table 2, describe the relationship between the line current and the motor speed for every position of the external rotor resistor (from position 1 to position 6).

TEST 2: Direct measurement of slip

1. Continued from TEST 1, set the external rotor resistor to position 6 (minimum).
2. Set the rotor current I_A to the values shown in Table 3 by adjusting the load torque (from the Control Unit). The rotor current I_A can be seen from the zero-centred ammeter. Record the measured motor speed (from the Control Unit) in Table 3. Measure the frequency of the rotor current by using the zero-centred ammeter. [Hint: To measure the frequency, when the needle of the zero-centred ammeter is oscillating (moving left and right), record the time duration for 30 oscillations]
3. Calculate the motor speed using slip $\boldsymbol{s = [(N_s - N) / N_s]}$ in Table 3, where $s = f_s / f$, N_s = synchronous speed (N_s = 1500 rpm) and N is the motor speed to be calculated.

Table 3 (External rotor resistor = position 6)

Rotor current I_A	Measured motor speed (rpm)	Time for 30 oscillations (t seconds)	Period for 1 osc. ($T = t/30$)	Slip frequency ($f_s = 1/T$)	Slip ($s = f_s / f$), f = 50Hz	Calculated motor speed N (rpm)	% difference between measured and calculated motor speed
0.9 A							
1.0 A							
1.1 A							
1.2 A							
1.3 A							

QUESTIONS:

1. In Table 3, what is the reason of the difference between the measured and calculated motor speed?
2. Mathematically, shows that at constant slip s and every resistance value of the rotor circuit, the total torque produced by the induction motor is almost directly proportional to the square of the supplied voltage.

TEST 3: Load test

A. Load test with zero resistance at the rotor circuit (position 6)

1. Set the external rotor resistance to minimum (position 6).
2. Turn ON the wattmeter. Increase the load in steps by adjusting the load torque (from Control Unit) to obtain the required line current in Table 4 and obtain the readings of line voltage (from voltmeter), input power (from wattmeter), motor speed and load torque (from Control Unit).

Table 4 (External rotor resistor = position 6)

Line current I_{line} (A)	Line voltage V_{line} (V)	Input power P_i (W)	Motor speed N (rpm)	Torque T (Nm)
2.1				
2.2				
2.3				
2.4				
2.5				

B. Load test with near maximum external rotor resistance (position 2)

1. Set the external rotor resistance to position 2.
2. Increase the load in steps by adjusting the load torque (from the Control Unit) to obtain the required line current in Table 5 and obtain the readings of line voltage, input power (from wattmeter), motor speed and load torque (from Control Unit).

Table 5 (External rotor resistor = position 2)

Line current I_{line} (A)	Line voltage V_{line} (V)	Input power P_i (W)	Motor speed N (rpm)	Torque T (Nm)
2.1				
2.2				
2.3				
2.4				
2.5				

C. Load test with constant line voltage

1. Turn ON the power factor meter.
2. Change the load torque to 0.6 Nm (using the Control Unit) and set the external rotor resistor to position 6. Record the line current, motor speed and power factor in Table 6. Repeat for different torque value.

Table 6 (External rotor resistor = position 6)

Line voltage V_{line} (V)	415							
Torque T (Nm)	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3
Line current I_{line} (A)								
Motor speed N (rpm)								
Power factor cos φ								
Output power $P_m = 2\pi NT/60$ (in W)								
$S = \sqrt{3} V_{line} I_{line}$ (in VA)								
Input power $P_i = S \cos \varphi$ (in W)								
Efficiency $\eta = P_m / P_i$								
Slip $s = (N_s - N) / N_s$, N_s = 1500 rpm								

* Precaution: Do not exceed 1.4 Nm for the torque. Ignore readings for Torque value that could not be achieved in the experiment

QUESTIONS:

1. From Tables 4, 5 and 6, plot the torque T vs. motor speed N. Explain your results.
2. From Table 6, plot a graph of motor output efficiency η vs. output power P_m. Explain your results.
3. From Table 6, plot the graph of speed, slip, P_m, line current and cos φ, versus torque T in one graph. Point out the nominal torque value in the graph. Describe the behaviour of the speed, slip, line current and cos φ when the torque is increased.

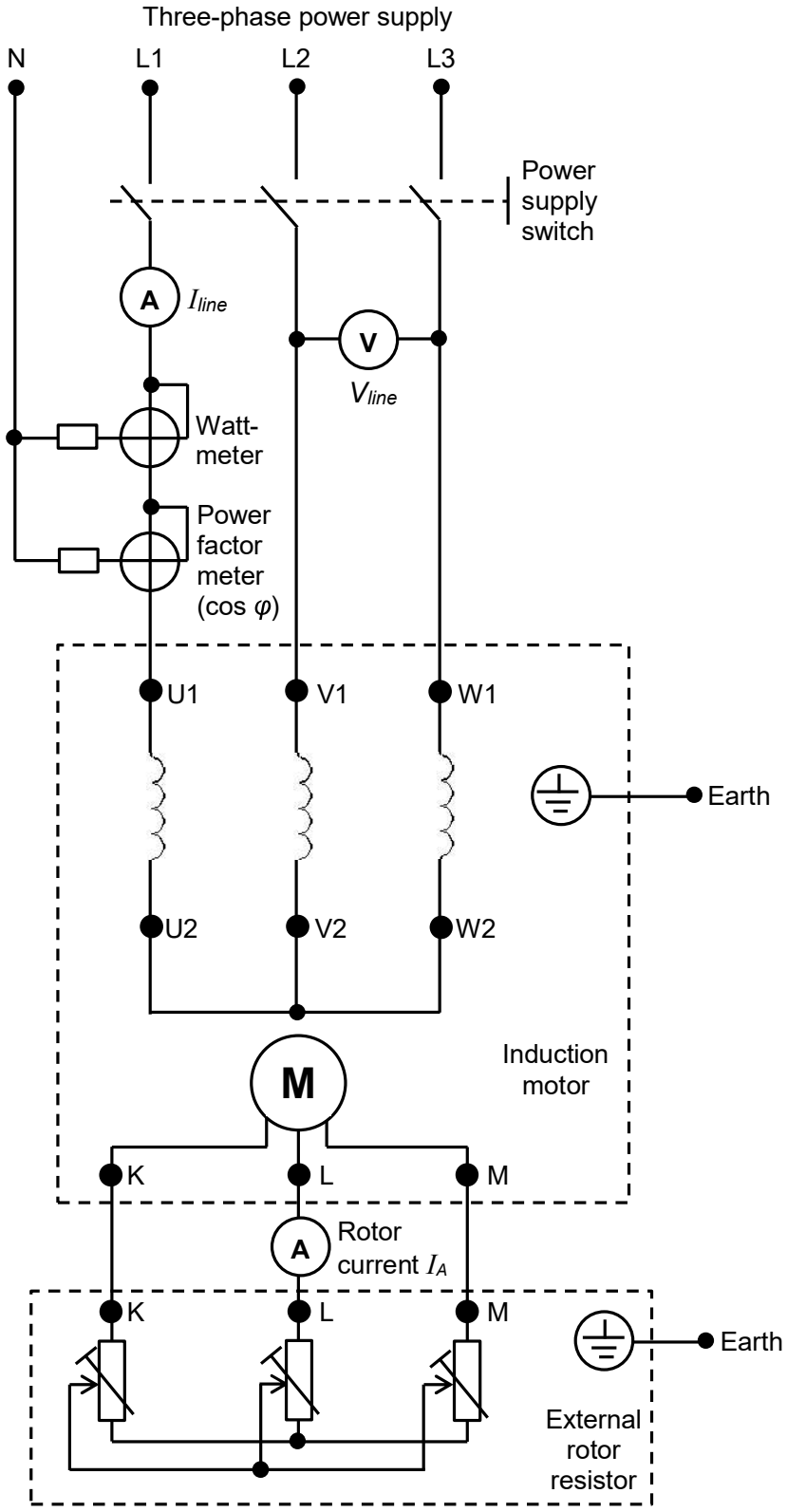


Figure 1

END OF EXPERIMENT