EXPERIMENT PE2: SPEED CONTROL OF A 3-PHASE INDUCTION MOTOR WITH FREQUENCY CONVERTER

Related course: KIE3008 (Power Electronics) or KEEE4265 (Power Electronics)

OBJECTIVES:

1. To assemble a circuit to control the speed of a three phase induction motor using frequency converter
2. To predict the output voltage and supply voltage to the load
3. To record the characteristics of speed / torque of the machine at various frequencies and characteristics of voltage / frequency
4. To determine the values of power and efficiency

EQUIPMENT:

Frequency converter, Isolation amplifier, Control unit, Three-phase induction motor, Digital oscilloscope, Analog multimeter

INSTRUCTIONS:

1. Record all your results and observations in a log book / paper
2. Follow the experiment procedure properly
3. Your circuit/connection must be checked by lab demonstrator/technician before the test is conducted

REFERENCE(S):

Refer to the main references of KIE3008 or KEEE4265

TESTS:

TEST 1: Load characteristics for motor
TEST 2: Load characteristics for motor at various frequencies
TEST 3: No-load test

INTRODUCTION:

The purpose of conducting this experiment is to investigate the control of a three-phase induction motor speed using a frequency converter and load characteristic of motor and its behaviour at different frequencies. A three-phase induction motor is a constant speed motor. Thus, it is difficult to control its speed. The speed control of induction motor is done at the cost of decrease in efficiency and low electrical power factor. The most basic type of control is the V/f control or frequency control, governed by

$$n_s = 120f/P$$

where f is the supply voltage frequency, P is the number of poles and n_s is the synchronous speed. In 3-phase induction motor, emf is induced by induction similar to transformer given by

$$E \text{ or } V = 4.44\varphi kNf$$

where k is the winding constant, N is the number of turns per phase and f is frequency. If we change the frequency, synchronous speed changes but with decrease in frequency, flux will increase and the change in the flux causes saturation of rotor and stator cores. This will further cause increase in no-load current of the motor. Thus, it is important to maintain flux φ constant and it is only possible if we change the voltage. If we decrease the frequency, flux increases but at the same time if we decrease the voltage, flux will also decease, causing no change in the flux and hence, it remains constant. Thus, we are keeping the ratio of V/f constant. Hence its name is V/f method. For controlling the speed of three-phase induction motor by V/f method, we have to supply variable voltage and frequency, which are easily obtained by using converter and inverter set.

TEST 1: Load characteristics for motor

1. Assemble the circuit as shown in Figure 1. Use 220V voltage source. Make sure that the connection is checked by the lab demonstrator or technician before switching ON the three-phase power supply.
2. Observe the 3-phase voltage supply using 4-channel isolation amplifier and digital oscilloscope. Sketch the waveforms.
3. Record the load characteristic in Table 1 for the motor, namely torque T (Nm), speed n (rpm), phase current I_{ph} and phase power P_{ph}.

Table 1

n (rpm)									
T (Nm)									
I_{ph} (A)									
P_{ph} (W)									

QUESTIONS:

1. From Table 1, draw graphs of n vs. T, I_{ph} vs. T and P_{ph} vs. T.
2. Give comments about the graphs obtained.

TEST 2: Load characteristics for motor at various frequencies

1. Assemble the circuit as shown in Figure 2, which the frequency converter is added in the arrangement from Figure 1.
2. Make sure that the switches positions on the frequency converter are: Switch A = OFF, Switch B = OFF, Switch C = ON.
3. Make sure that the "Set/Start value" knob on the Control Unit is positioned at zero value (set as 10 on the knob).
4. Make sure that the connection is correct before switching ON the main switch.
5. Change switch C position from "ON" to "OFF" and then "ON" again. Repeat step 5 if the motor still does not turn.
6. Adjust the frequency knob at frequency converter to vary the motor speed.
7. Record load characteristics for the motor at various speed. Complete Table 2.

Table 2

No-load speed, n_0 = 1000 rpm

n (rpm)									
T (Nm)									
I_{ph} (A)									
P_{ph} (W)									

No-load speed, n_0 = 1400 rpm

n (rpm)									
T (Nm)									
I_{ph} (A)									
P_{ph} (W)									

No-load speed, n_0 = 1800 rpm

n (rpm)									
T (Nm)									
I_{ph} (A)									
P_{ph} (W)									

No-load speed, n_0 = 2200 rpm

n (rpm)									
T (Nm)									
I_{ph} (A)									
P_{ph} (W)									

No load speed, n_0 = 2600 rpm

n (rpm)									
T (Nm)									
I_{ph} (A)									
P_{ph} (W)									

No load speed, n_0 = 3000 rpm

n (rpm)									
T (Nm)									
I_{ph} (A)									
P_{ph} (W)									

TEST 3: No-load test

1. Measure the motor line voltage, frequency and torque for every speed without loading (no-load speed). Complete Table 3.

Table 3

No-load speed (rpm)								
Motor line voltage (V)								
Motor frequency (Hz)								
Torque *T* (Nm)								

QUESTIONS:

1. From Table 3, draw the efficiency vs. torque graph. Notes:
   3-phase input power = 3 x single phase power (P_{ph})
   Mechanical power = $2\pi nT/60$, where *n* = motor speed (rpm), *T* = torque (Nm)
   Mechanical efficiency = (Mechanical power) / (3-phase input power)
2. From Table 3, draw the following graphs:
   a) Motor line voltage vs. frequency
   b) No-load speed vs. frequency
   c) Efficiency vs. frequency
3. Give comments about the results obtained.

END OF EXPERIMENT

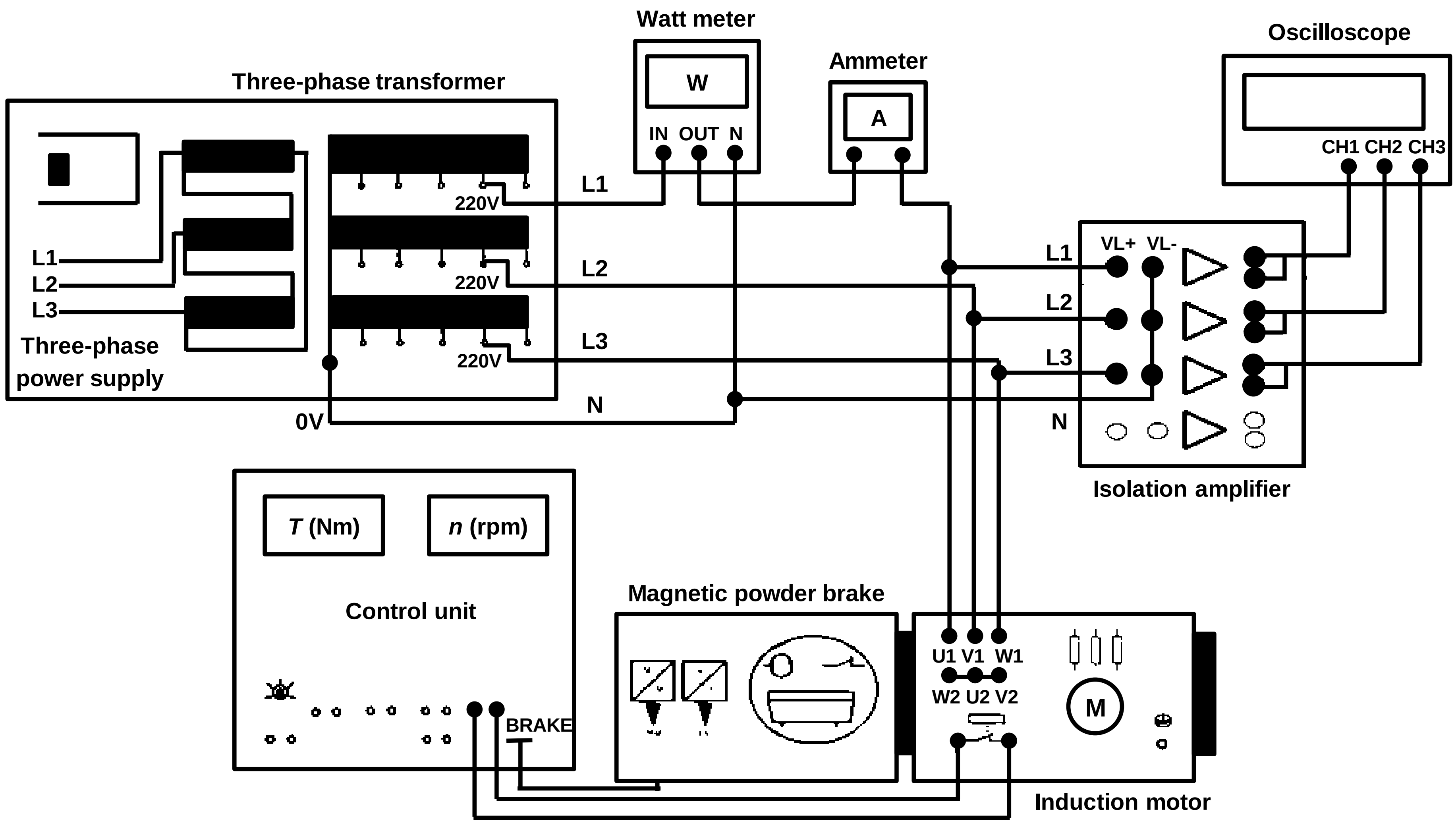
Watt meter
W
IN OUT N
Ammeter
A
Oscilloscope
CH1 CH2 CH3
Three-phase transformer
220V
220V
220V
L1
L2
L3
N
0V
L1
L2
L3
Three-phase
power supply
VL+ VL-
L1
L2
L3
N
Isolation amplifier
T (Nm)
n (rpm)
Control unit
BRAKE
Magnetic powder brake
U1 V1 W1
W2 U2 V2
M
Induction motor

Figure 1

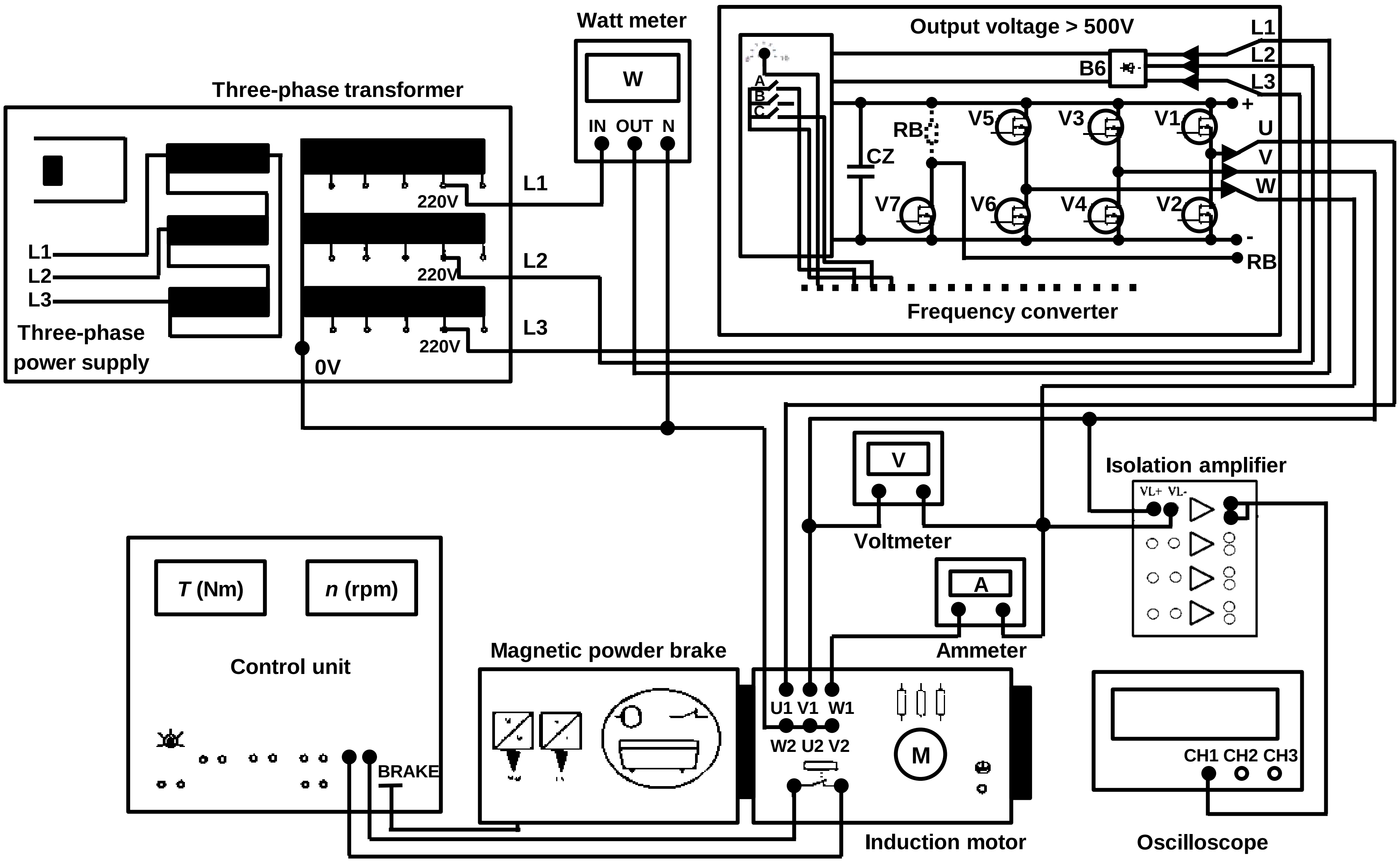
Watt meter
W
IN OUT N
Output voltage > 500V
L1
L2
L3
B6
A
B
C
RB
CZ
V5
V3
V1
V7
V6
V4
V2
+
U
V
W
-
RB
Frequency converter
Three-phase transformer
220V
220V
220V
L1
L2
L3
0V
Three-phase power supply
Isolation amplifier
VL+ VL-
V
Voltmeter
A
Ammeter
T (Nm)
n (rpm)
Control unit
BRAKE
Magnetic powder brake
U1 V1 W1
W2 U2 V2
M
Induction motor
CH1 CH2 CH3
Oscilloscope

Figure 2