EXPERIMENT MD1: THREE PHASE INDUCTION MOTOR

Related course: KIE2009 (Machines and Drives)

OBJECTIVES:
To study the characteristics of three phase induction motor

EQUIPMENT:

Item	Description	Qty	Model
1	Three Phase Power Supply	1	EM-30-09-01
2	Three Phase Induction Motor	1	EM-30-02-01
3	Three Phase Synchronous Machine	1	EM-30-03-02
4	AC Variable Frequency Drive	1	EM-30-14-02
5	Push Button Switch Module (I)	1	EM-10-08-01
6	Tachometer	1	DT-2234C
7	Laboratory Table	1	EM-30-16-01-02
8	Experimental Panel Frame	1	EM-30-16-02-02
9	4mm Safety Stackable Leads Set	1	EM-30-15-01
10	Universal AC/DC Phase Power Supply	1	EM-30-09-02-01

INSTRUCTIONS:
1. Record all your results and observations in a log book / paper.
2. Do not change the circuit connection without permission from the lab demonstrator or technician.
3. Always let the lab demonstrator check your circuit before turning on the power.

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

TESTS:
Test 1: Motor Operation - STAR Connection
Test 2: Motor Operation - DELTA Connection
Test 3: Motor Operation - Controlling The Direction Of Rotation
Test 4: Speed Control By AC Variable Frequency Drive In STAR Connection. (Panel Control Start/Stop Function)
Test 5: Directional Control by AC Variable Frequency Drive In STAR Connection. (Terminal control Start/Stop)

CAUTION!
HIGH VOLTAGE!!

HANDLE THE EQUIPMENT WITH EXTREME CARE AS HIGH VOLTAGES ARE PRESENT AT SOME SOCKETS AND EXPOSED TERMINAL.

RECOMMENDATION FOR SAFE AND EFFICIENT OPERATION:

Owing to the versatility and characteristics of this electrical machine training aid, the following measures must be adhered to:

1) The supply to the machines must be protected by earth leakage.

2) All connections must be terminated correctly at both ends before power is connected.

3) No exposed conductive parts of connection must be visible after the connection.

4) No connections must be disconnected whilst power is still connected.

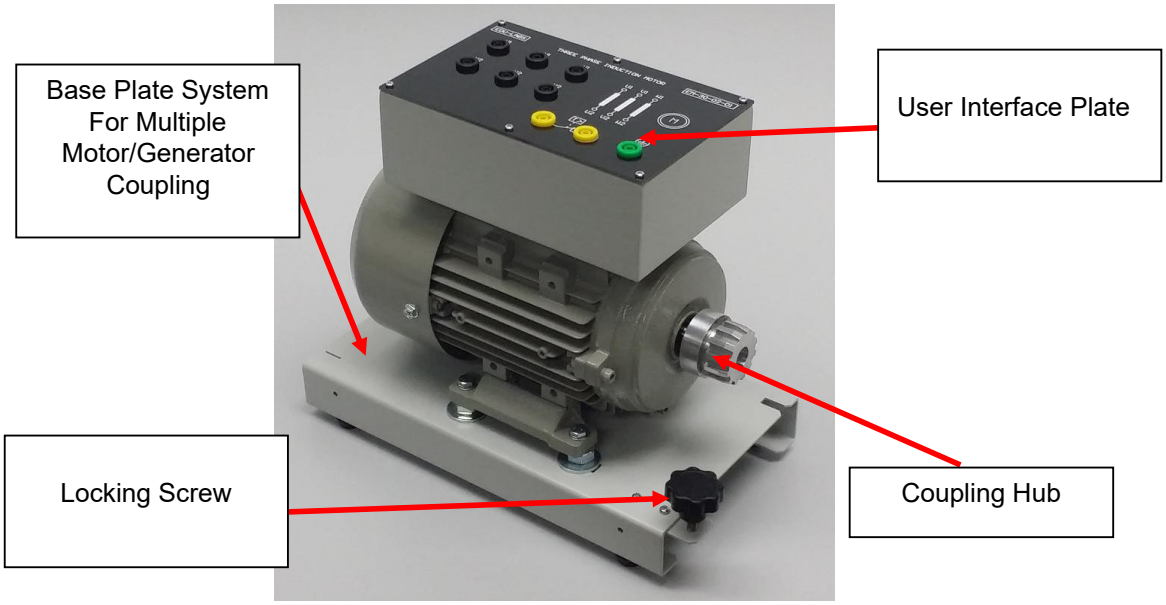
5) Brushes must not be observed or adjusted whilst power is still connected.

6) Coupling must be done before power is connected,

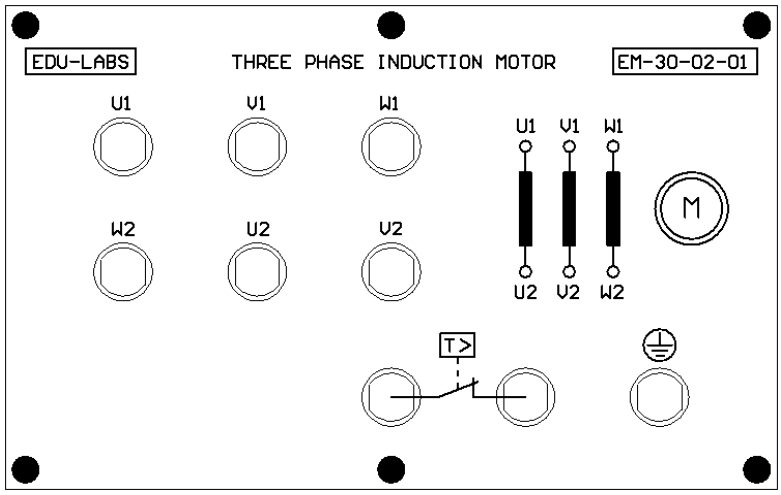
7) Instructions specified in individual assignments must be adhered to.

8) Further experiments or variation must be done only after the teacher consent.

INTRODUCTION:



User interface plate:



Technical characteristics:

Power : 370W	Speed : 3000 rpm	Protection: Optional Temperature Switch
Voltage: 415V / 240V STAR / DELTA	Current: 1.05A / 1.65A STAR / DELTA	Power Factor : 0.81

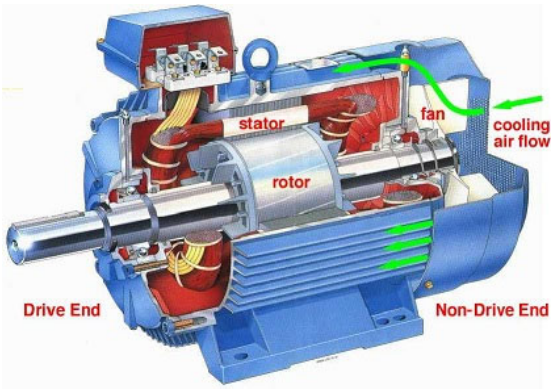
The induction machine is used as the most common motors in different applications. It is the Workhorse of industry. It has a stator and a rotor like other type of motors. There can be two different types of rotor:

- squirrel-cage winding rotor
- Wound-rotor

Both three-phase and single-phase motors are widely used. Majority of the motors used by industry are squirrel-cage induction motors. Induction machines have many advantages:

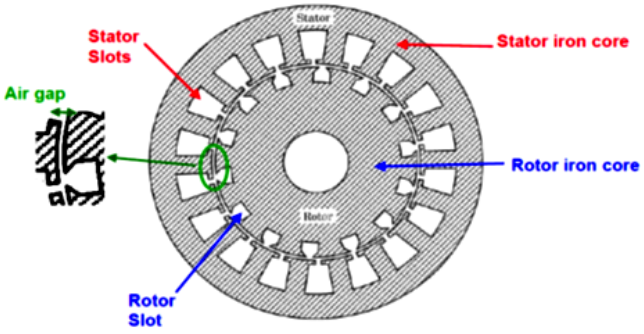
- Rugged, Reliable, and Easy to maintain.
- Relatively inexpensive.
- Easy to reverse the rotation.
- Lighter than some other types motor for the same power rating.

A typical induction machine consists of two parts: a stator which is the outside stationary frame having coils supplied with AC current to produce a rotating magnetic field and a rotor which is in the inside and attached to the output shaft that is given a torque by the rotating field.



Stator construction:

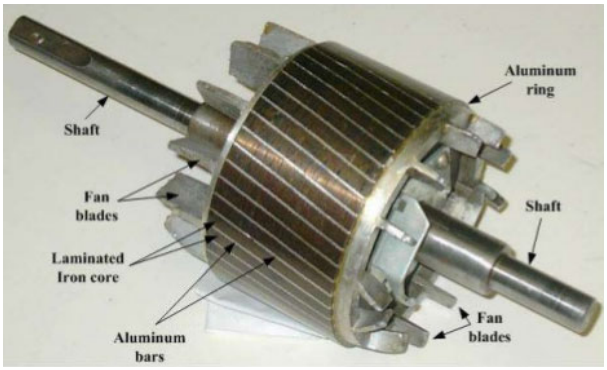
The stator of an induction motor is laminated iron core with slots. Coils are placed in the slots to form a three or single phase winding.



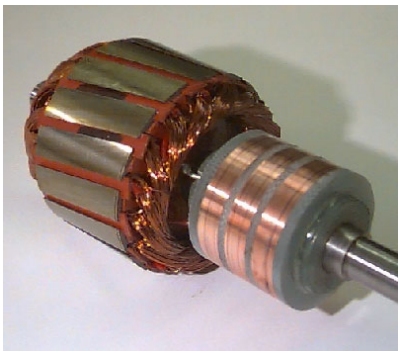
Rotor Construction:

Metal (Aluminum) bars are molded in the slots instead of a winding.
Two different types of rotors:

- squirrel-cage winding

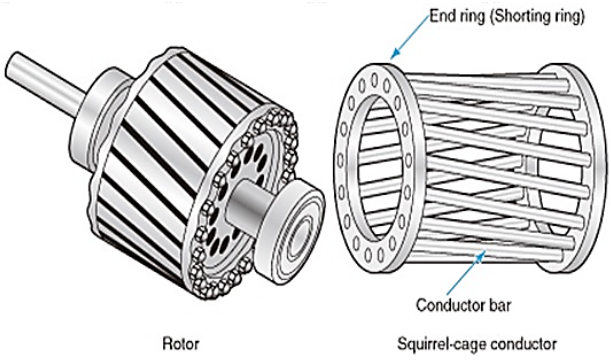


- Wound-rotor



Squirrel-Cage Rotor:

Winding is made of aluminum bars embedded in the rotor slots. Each bar is short-circuited at both ends by end rings. The skewing is done to produce a more uniform torque and to reduce the noise during operation. One or two fans are attached to the shaft in the sides of rotor to cool the circuit.



Wound Rotor:

It is usually for large 3 phase induction motors. Rotor has a winding the same as stator and the end of each phase is connected to a slip ring. Three brushes contact the three slip-rings

to three connected resistances (3-phase Y) for reduction of starting current and speed control. Compared to squirrel cage rotors, wound rotor motors are expensive and require maintenance of the slip rings and brushes, so it is not so common in industry applications.

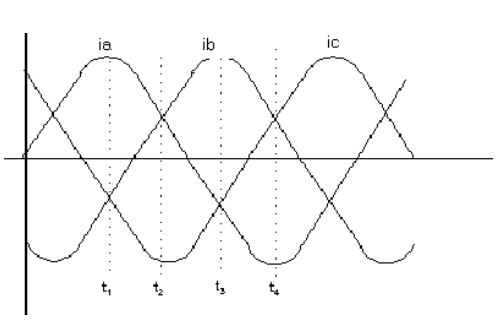
Principle of Operation of Three-phase Induction Motor:

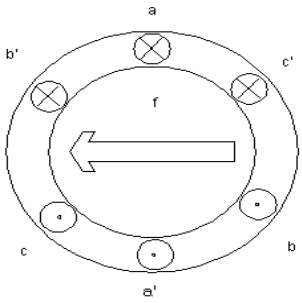
When the stator winding is connected to a balanced three-phase supply, current will flow in each phase winding. The currents are equal magnitude, but differing in phase by 120°. Each phase current produces a magnetic flux and there is physical 120° shift between each flux. The total flux in the machine is the sum of the three fluxes. The summation of the three AC fluxes results in a rotating flux, which turns with constant speed and has constant amplitude. Such a magnetic flux produced by balanced three phase currents flowing in three-phase windings is called a rotating magnetic flux (RMF). RMF rotates with a constant speed (Synchronous Speed).

Production of Rotating Magnetic Field:

At the time t = t1, the current ia is positive and ib and ic are negative. It is assumed that for positive currents the current will enter the windings at a, b and c, and directed into the page.

The current direction in the phase windings at t1 is illustrated in Figure. The cumulative effect of these currents is that the magnetic field is directed to the left.



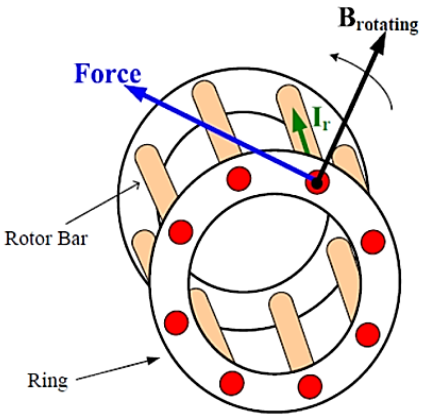


How does the rotor rotate?

The stator is supplied by 3-phase voltages that drive three- phase balanced current through the windings. The 3-phase stator currents generate a rotating magnetic field. (Let the flux density be $B_{rotating}$). The field rotates at synchronous speed.

The rotating field induces a voltage in the short-circuited rotor conductors. The induced voltage is given by E= (B x L).v (Faraday's Law) where L is the length of the rotor.

The induced voltage generates current in the bars. The interaction between the rotor current and the stator field produces a force or torque (Lorentz force) that drives the motor: F= (B x I).L



$$N = \frac{120\,f}{P}$$

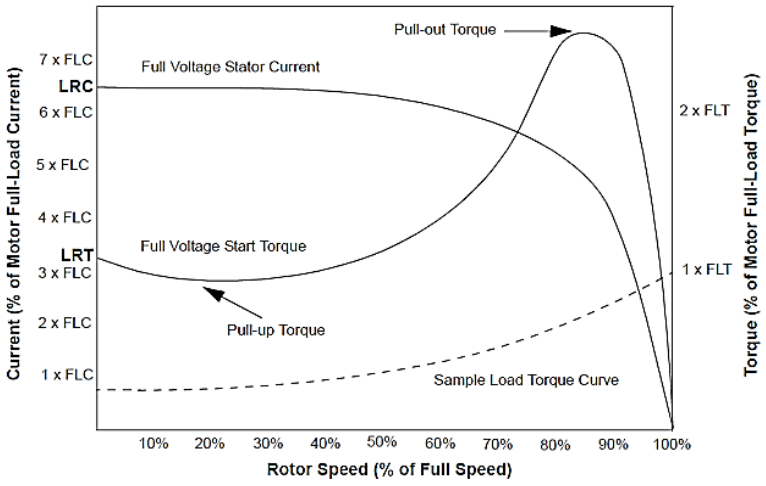
Where N = Synchronous speed

f = Frequency

P = Number of poles

The stator magnetic field (rotating magnetic field) rotates at a speed, ***N* the synchronous speed**.

The torque-speed curve of the typical three phase induction motor is shown in below:



TEST 1: Motor Operation - STAR Connection

1. Construct the following circuit.

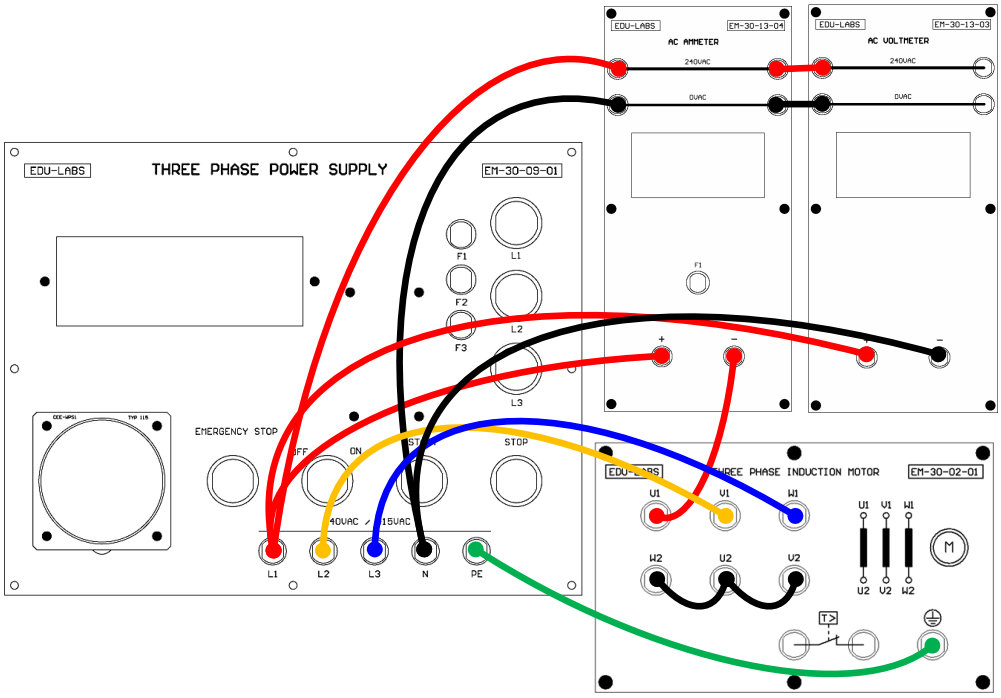


Fig. 1: Star connection

2. Connect the Three Phase Power Supply L1 to the Ammeter before connected to the Three Phase Induction Motor U1, V1, W1 and make sure that the connection is STAR connection in U2, V2, W2 as in Fig.1.
3. Press START button to ON the Three Phase Power Supply, record the Voltage in Table 1 then STOP button to OFF the Power Supply.

Table 1: Star connection

NO	Input Voltage (V)			Input Current (A)			RPM
	L1-L2	L2-L3	L3-L1	L1-L2	L2-L3	L3-L1	
1							

TEST 2: Motor Operation - DELTA Connection

1. Construct the following circuit.

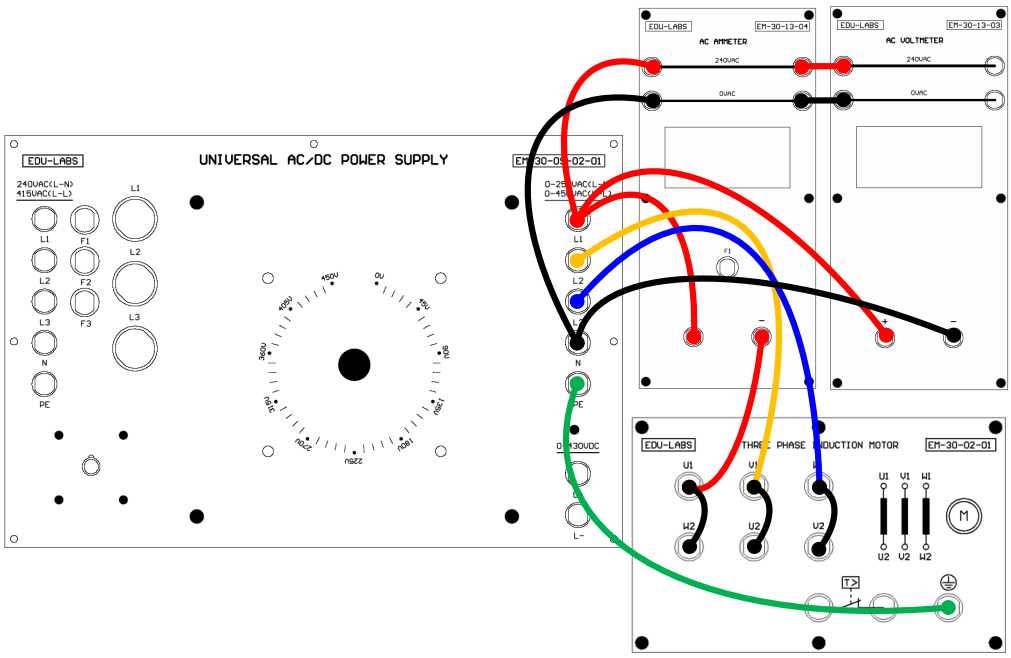


Fig. 2: Delta Connection **(THREE PHASE 240V SUPPLY ONLY)**
WARNING: ONLY APPLY THREE PHASE 240VAC FOR DELTA CONNECTION, COIL WILL BURN IF APPLY THREE PHASE 415VAC

2. Connect the Universal AC/DC Power Supply L1, L2, L3 to the Ammeter & Voltmeter before connected to Three Phase Induction Motor U1, V1, W1 and make sure that the connection is DELTA connection in U2, V2, W2 as in Fig.2, Connect the earth of the motor.
3. Adjust the Power Supply Knob to set the voltage to **Three Phase 240V** record the Voltage in Table 1 then switch it off.

Table 2: Delta connection

NO	Input Voltage (V)			Input Current (A)			RPM
	L1-L2	L2-L3	L3-L1	L1-L2	L2-L3	L3-L1	
1							

TEST 3: Motor Operation - Controlling the Direction Of Rotation

1. Construct the following circuit, switch ON the Power Supply, observe the rotation direction, and record your observation.

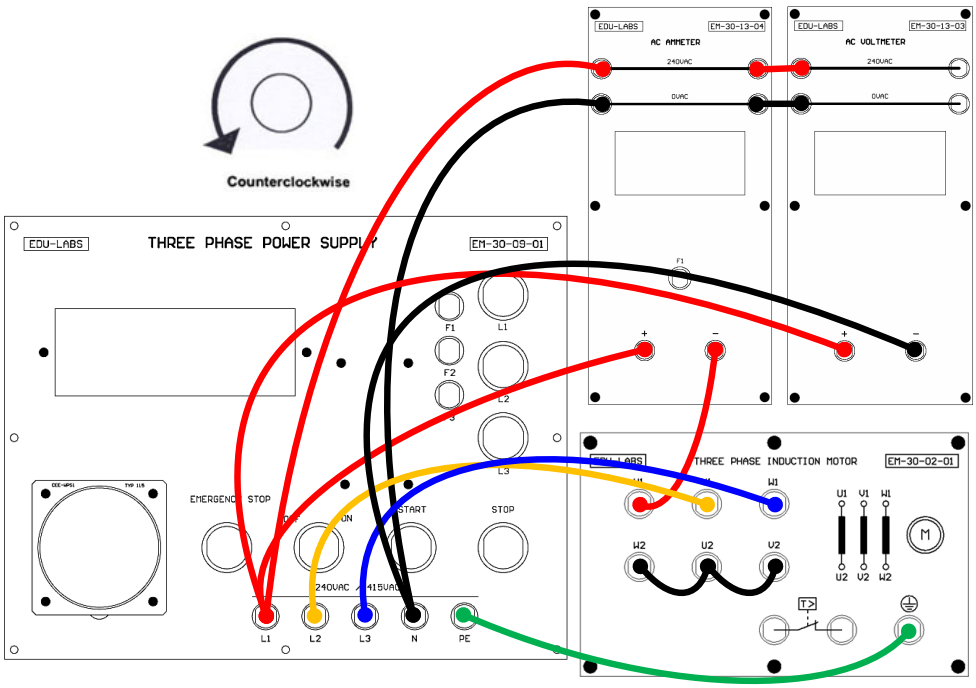


Fig. 3: Star connection

2. Turn OFF the Power Supply, exchange the connection for L1 and L2 to U1 and U2. Switch ON the power supply, observe the rotation direction, and record your observation.

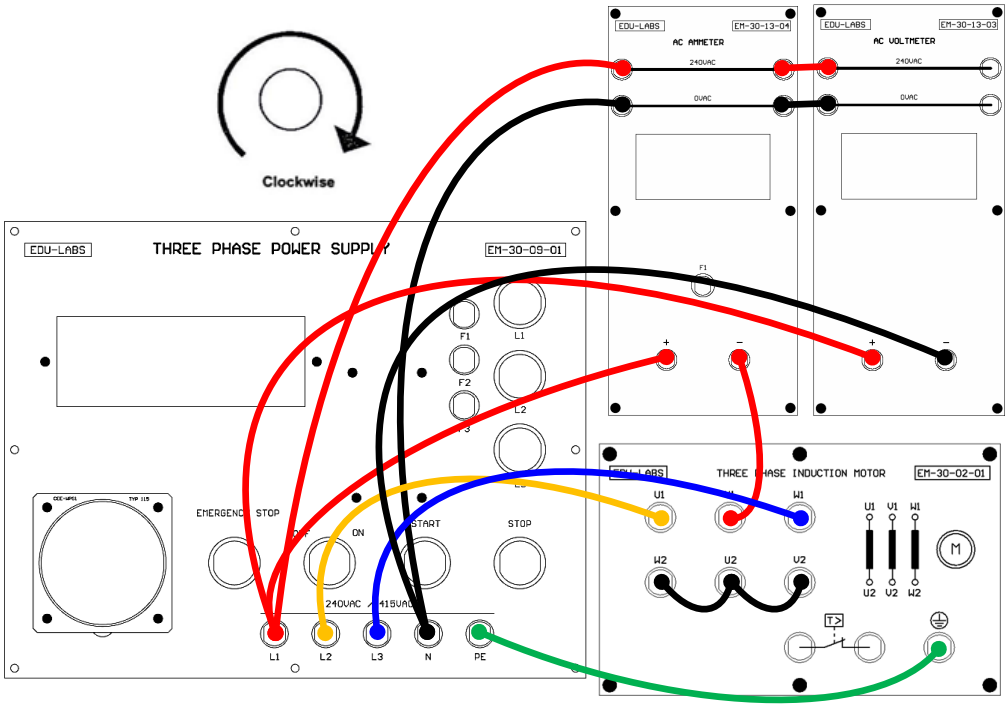


Fig. 4: Star connection (different phase)

TEST 4: Speed Control By AC Variable Frequency Drive In STAR Connection. (Panel Control Start/Stop Function)

1. Construct the following circuit.

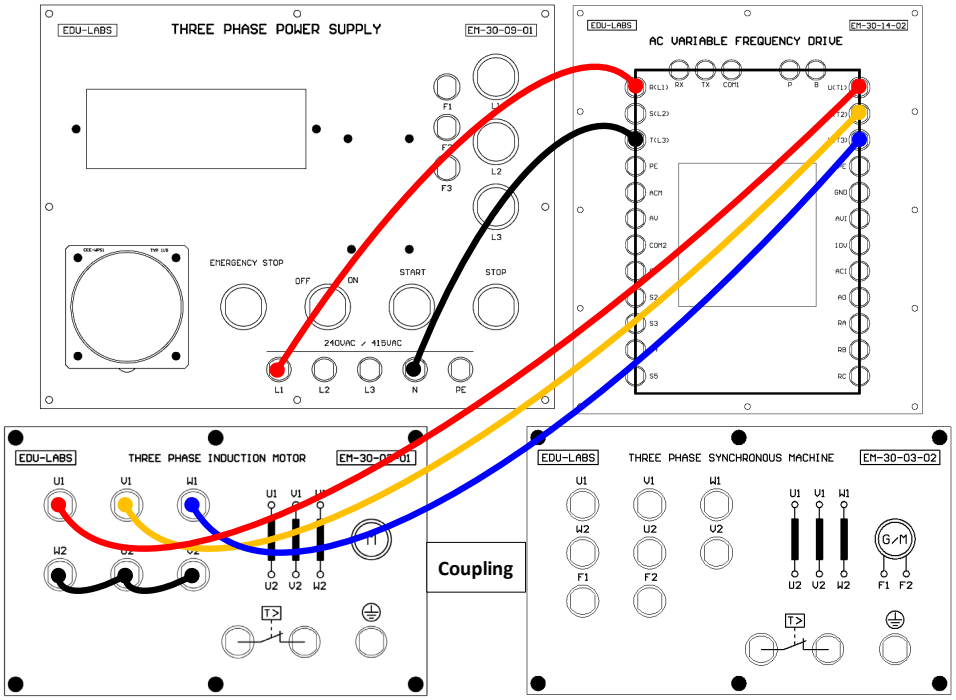


Fig. 5: AC Variable Frequency Drive Wiring Connection

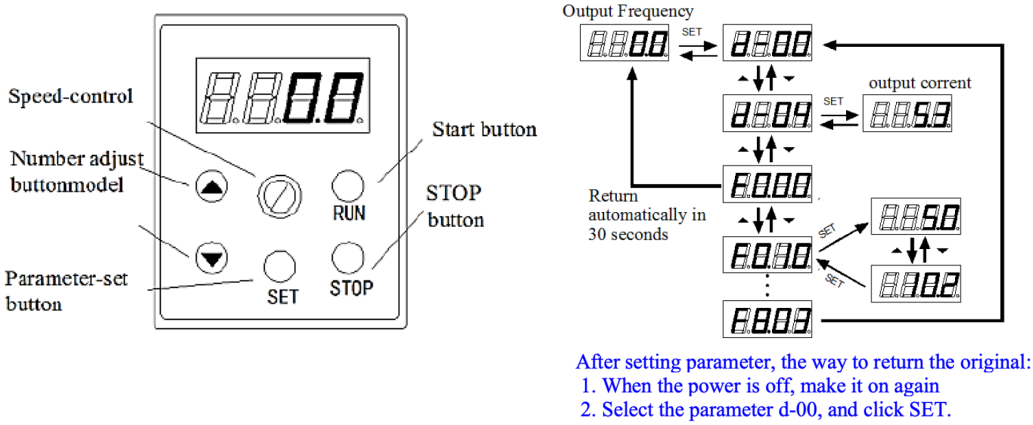


Fig. 6: AC Variable Frequency Drive Wiring Connection

2. Set the AC Variable Frequency Drive to Panel Control Mode F0.02 : 0.
3. Connect the Three Phase Power Supply EM-10-09-01 terminals L1 and N to the AC Variable Frequency Drive terminal R(L1) and S(L3), and U(T1), V(T2) & W(T3) to Three Phase Induction Motor U1, V1, and W1 and make sure that the connection is STAR connection in U2, V2, and W2 as in Fig. 6.

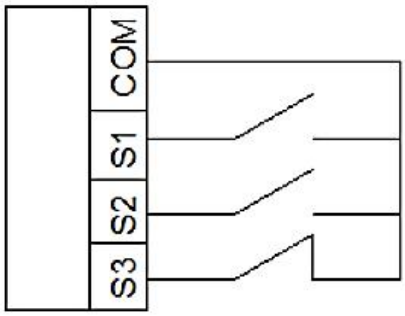
4. Switch ON the Three Phase Power Supply, Adjust the frequency knob of AC Variable Frequency Drive according to the Table 3 by different Frequency.
5. Record the Results in Table 3.

Table 3: Speed Control In STAR Connection

NO	FREQ	FREQ (MANUAL SETTING)	RPM
1	10		
2	20		
3	30		
4	40		
5	50		

TEST 5: Directional Control by AC Variable Frequency Drive In STAR Connection. (Terminal control Start/Stop)

Three-wire Control Model 1



Public end

Connect FWD, keep FWD when disconnected

Connect REV, keep FWD when disconnected

Stop when disconnected

Parameters: F2.13 = 3, F2.14 = 4, F2.15 = 5, F2.18 = 2

1. Make sure SET the AC Variable Frequency Drive to Terminal Control Mode by set F0.02: 1 (Factory Default F0.02:0 for Panel Control Mode).
2. Connect the Three Phase Power Supply Module EM-10-09-01 U, V and W to the Three Phase Induction Motor U1, V1, and W1 and make sure that the connection is STAR connection in U2, V2, and W2 as in Fig.7.
3. Construct the circuit by using Push Button Switch Module (I) to AC Variable Frequency Drive according to the schematic diagram Three-wire Control Model 1.
4. Switch ON the Three Phase Power Supply Module.
5. Push the Push Button Switch 1, 2 and 3 according to the Function (FORWARD, REVERSE & STOP)
6. Observe the motor and record your observations.

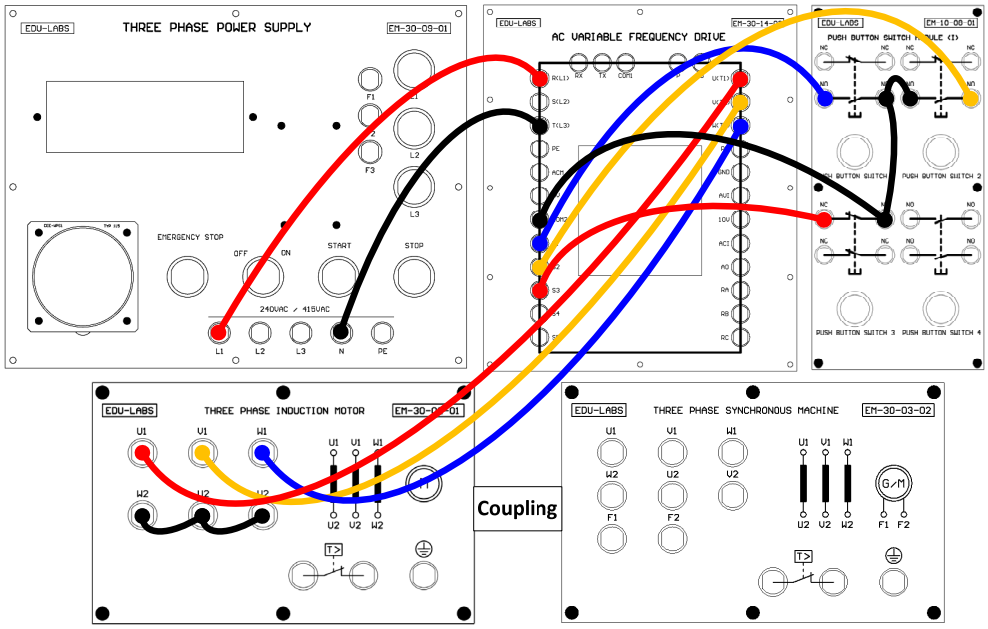


Fig. 7: AC Variable Frequency Drive Wiring Connection
(FORWARD, REVERSE & STOP)

QUESTIONS:

1. Discuss the difference of operating the three-phase motor in star and delta mode.
2. What happens if the motor is connected to Delta connection at starting?
3. What happens if the motor is always connected to the Star Connection?

END OF EXPERIMENT